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Investigating perception and attention to emotional expressions in the autism spectrum

Pip Griffiths

A thesis submitted for the degree of Doctor of Philosophy

University of Bath

Department of Psychology

2014

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## Table of Contents

Abstract.....	8
Chapter 1.....	9
Literature Review .....	9
Chapter Summary .....	9
Defining Autism Spectrum Conditions (1.1).....	9
Social and Emotion processing ability in ASC (1.2) .....	11
Social processing ability in ASC (1.2.1).....	11
Emotion expression processing in ASC (1.2.2) .....	12
The Spectrum of Autism Traits (1.3) .....	17
Broader Autism Phenotype (1.3.1) .....	17
The Wider Autism Spectrum (1.3.2) .....	19
Social and Emotion processing ability in the WAS (1.4) .....	21
Social ability variation in the WAS (1.4.1) .....	21
Emotion expression processing in the WAS (1.4.2) .....	23
Relevant theories of autism (1.5).....	25
Weak Central Coherence (WCC) account (1.5.1) .....	25
Empathising-Systemising theory of autism (1.5.3) .....	28
The amygdala theory of autism (1.5.2) .....	30
The social motivation theory of ASC (1.5.4).....	31
Chapter 2.....	34
Participant Justification and Selection .....	34
Theoretical framework (2.1) .....	34
ASC spectrum (2.2).....	34
ASC-Group (2.3) .....	36
Control Group for ASC Studies (2.4) .....	37
Participant Specifics (2.5).....	38
Wider Autism Spectrum Participants (Chapters 3-6) (2.5.1) .....	38
Chapter 3 & 4 Participant Inclusion (2.5.2) .....	40
Chapter 3 Participant Specifics and Power Analysis (2.5.3).....	40
Chapter 4 Participant Specifics and Power Analysis (2.5.4).....	41
Chapter 5 Participant Specifics and Power Analysis (2.5.5).....	42
Chapter 6 Participant Specifics and Power Analysis (2.5.6).....	43
Autism Spectrum Condition Participants (Chapters 7 & 8) (2.5.7) .....	43
Chapter 7 & 8 Participant Specifics (2.5.8) .....	46

Chapter 3 – Study 1.....	48
Using Visual Adaptation to Explore the Mechanisms of Emotion Processing in the Wider Autism Spectrum.....	48
Introduction .....	48
Visual Adaptation (3.1) .....	48
Visual Adaptation (3.1.1) .....	48
Understanding Adaptation (3.1.2) .....	48
The Neural Fatigue Theory (3.1.3) .....	50
The Functional Account (3.1.4).....	51
Neural Coding of Social Stimuli (3.1.5).....	53
Variant and Invariant Information in face processing (3.1.6) .....	54
Adaptation to social information (3.1.7).....	56
Adaptation to social information in ASC (3.1.8) .....	61
Aims and hypotheses (3.1.9).....	64
Method (3.2) .....	65
Participants (3.2.1).....	65
Stimuli (3.2.2).....	65
Emotion Recognition and Valence recognition baseline tasks (3.2.2.1).....	65
Tilt Adaptation Baseline Task (3.2.2.2) .....	66
Procedure (3.2.3) .....	67
Emotion recognition task (3.2.3.1) .....	67
Valence recognition baseline task (3.2.3.2) .....	68
Tilt Adaptation Baseline Task (3.2.3.3) .....	68
Emotion Expression Adaptation (3.2.3.4) .....	69
Results (3.3).....	71
Demographics (3.3.1).....	71
Emotion feature recognition tasks (3.3.2) .....	71
Emotion valence task (3.3.3).....	72
Tilt adaptation baseline task (3.3.4) .....	73
Anti-expression adaptation task (3.3.5).....	74
Discussion.....	78
Chapter 4 – Study 2.....	83
Using the dot-probe paradigm to study attention mechanisms to emotional faces in the Wider Autism Spectrum.....	83
Introduction (4.1).....	83
Attention Tasks (4.2) .....	83

Modified Stroop Task (4.2.1) .....	84
The Visual Probe Task (4.2.2) .....	84
The dot-probe paradigm (4.2.3) .....	85
The Cognitive-Motivational Theory (4.2.4) .....	86
Visual-probe in ASC and the WAS (4.3) .....	88
Methodological considerations (4.5) .....	91
Probe detection (4.5.1) .....	91
Probe Classification (4.5.2) .....	91
Timing considerations (4.5.3) .....	92
Stimuli considerations (4.5.4) .....	93
Aims and hypotheses (4.6) .....	93
Method (4.7) .....	95
Participants (4.7.1) .....	95
Stimuli (4.7.2) .....	95
Procedure (4.7.2) .....	95
Results (4.8) .....	97
Discussion (4.9) .....	101
Chapter 5 – Study 3 .....	106
Using Eye tracking to explore the difference in attention to features of the emotional face across the autism spectrum .....	106
Introduction (5.1) .....	106
Aims and hypotheses (5.2) .....	109
Method (5.3) .....	111
Participants (5.3.1) .....	111
Stimuli (5.3.2) .....	111
Procedure (5.3.3) .....	112
Analysis specifications (5.3.4) .....	113
Defining Regions of Interest (RoI) (5.3.4.1) .....	113
Defining Fixations and Dwell time (5.3.4.2) .....	115
Data Preparation (5.3.5) .....	115
Statistical procedure (5.3.6) .....	116
Results (5.4) .....	117
Voluntary attention to facial features (5.4.1) .....	117
Fixations in the Eye ROI (5.4.1.1) .....	117
Fixations towards the Mouth Region (5.4.1.2) .....	117
Dwell Time for the Eye Region (5.4.1.3) .....	117

Dwell time for the Mouth Region (5.4.1.4).....	117
Ratio of fixations between eyes and mouths (5.4.1.5) .....	117
Initial attention for facial features (5.4.2).....	118
First Fixation Data (5.4.2.1).....	118
First Fixations to the eye region.....	118
First Fixations to the mouth region.....	119
Within Group First Fixations to Eye and Mouth Regions.....	119
First fixations away from the point of initial fixation.....	119
Analysis of bias to the eye region .....	120
Initial Fixation at the Centre of the face (5.4.2.2).....	120
Initial Fixation at the Mouth region (5.4.2.3).....	121
Initial Fixation at the Eye region (5.4.2.4).....	121
Discussion (5.5) .....	122
Chapter 6 – Study 4 –.....	129
Testing the recognition of mild facial expression in those with high and low ASC-traits. .....	129
Introduction (6.1).....	129
Aims and hypotheses (6.2).....	131
Method (6.3) .....	133
Participants (6.3.1).....	133
Stimuli (6.3.2).....	133
Procedure (6.3.3) .....	133
ER40 procedure (6.3.3.1) .....	134
Results (6.4).....	135
Emotion Recognition.....	135
Accuracy Data (6.4.1).....	135
Reaction Time Data (6.4.2) .....	136
Error Analysis (6.4.3).....	138
Discussion (6.5) .....	140
Chapter 7 – Study 5 –.....	144
Using Visual Adaptation to Explore the Mechanisms of Emotion Processing in ASC.....	144
Introduction (7.1).....	144
Aims and hypothesis (7.2).....	149
Methods (7.3).....	150
Participants (7.3.1).....	150
Stimuli (7.3.2).....	150

Full Face Emotion Recognition (7.3.2.1) .....	150
Tilt aftereffect (7.3.2.2).....	150
Adaptation task (7.3.2.3) .....	150
Procedure (7.3.3) .....	150
Full face emotion recognition (7.3.3.1).....	150
Tilt aftereffect (7.3.2.2).....	151
Adaptation task (7.3.2.3) .....	151
Results (7.4).....	152
Full Face Emotion Recognition (7.4.1) .....	152
Tilt Adaptation Baseline Task (7.4.2) .....	153
Emotion Expression Adaptation (7.4.3) .....	153
Anti-expressions at 50% and 100% representational strength (7.4.3.1) .....	153
Anti-expressions and typical expressions analysis (7.4.3.2) .....	156
Possible contribution of emotion expression recognition ability (7.4.3.3).....	158
Discussion (7.5) .....	159
Chapter 8 – Study 6.....	164
Using a visual-probe paradigm to study attention to emotional faces in autism .....	164
Introduction (8.1).....	164
Method 8.2.....	168
Participants (8.2.1).....	168
Stimuli (8.2.2) .....	168
Procedure (8.2.3) .....	168
Results (8.3).....	169
Outlier Data (8.3.1) .....	169
Group differences following outlier removal (8.3.2) .....	170
Dot-probe Analysis (8.3.3) .....	170
Discussion (8.4) .....	176
Chapter 9.....	180
General Discussion.....	180
Overview of findings from Wider Autism Spectrum (Chapters 3-6) (9.1) .....	180
Chapter 3 (9.1.1) .....	180
Chapter 4 (9.1.2) .....	181
Chapter 5 (9.1.3) .....	183
Chapter 6 (9.1.4) .....	184
Summary (9.1.5).....	184
Overview of findings from ASC (Chapters 7&8) (9.2) .....	185

Chapter 7 (9.2.1) .....	185
Chapter 8 (9.2.2) .....	187
Summary (9.2.3) .....	187
The social motivation theory and the spectrum of autism (9.3) .....	188
Limitations (9.5) .....	189
Directions for Future Work (9.6) .....	190
Concluding Remarks (9.7) .....	192
References .....	193

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# Abstract

Autism spectrum condition (ASC) is a lifelong developmental condition. Along with restricted interests and deficits in social imagination, people with ASC have difficulty understanding the social world. Evidence suggests that ASC individuals have difficulty understanding the emotional expressions of others, particularly when these expressions have negative valence.

It is suggested that ASC is not a discrete phenomenon. Instead research has shown that traits associated with autism are seen in varying levels throughout the general population. It is believed that ASC is a spectrum, with those who have the most difficulty obtaining a diagnosis.

The traits of autism present in the general population are seen to be qualitatively similar to those seen in ASC. It is therefore suggested that the ASC can be explored and further understood by assessing people in the Wider Autism Spectrum (WAS) of ASC-traits who do not hold a diagnosis. This research contributes to the understanding of the WAS and how ASC-traits manifest in the general population. Additionally, the differences between ASC and the WAS can be assessed by comparing the performance of people with a diagnosis to those in the WAS who have high ASC-traits. Through understanding the differences between these populations we are better able to understand what drives the clinical impairments associated with ASC.

The current thesis assesses facial emotion processing in people with ASC and those in the WAS in order to understand the differences and similarities that exist. This was conducted using several cognitive tasks that assess the underlying brain mechanisms associated with facial emotion processing. Directed by the social motivation theory of autism, the current work used visual adaptation paradigms to assess how the brain represents emotional expression information in those with ASC and people with high and low ASC-traits. Additionally, the dot-probe paradigm was employed to explore attentional orienting for emotional expressions in ASC and the WAS.

Results found that WAS participants with high ASC-traits do not represent negative emotional expressions in the same way as those with fewer ASC-traits. When assessing attention mechanisms those with high autism-traits were more likely to bias attention towards emotional expression information. Results suggests that WAS individuals with high ASC-traits process emotional faces differently from their low ASC-trait counterparts and also have a different way of selecting which emotions to attend to in their environment.

People with ASC had deficits in mental representation of emotional expression but did not show the same pattern of attention to emotional expressions seen in high ASC-trait WAS individuals. These results do not suggest the autism spectrum is linear. Results are discussed suggesting that those with high traits of autism have a profile of behaviour that cannot be explained by the social motivation theory whereas ASC results do follow predictions this theory makes.

# Chapter 1

## Literature Review

### Chapter Summary

This chapter aims to define and elaborate on where the clinical definition of Autism Spectrum Conditions (ASC) arose from. Emotion expression identification both in typical development and ASC will be discussed in order to ascertain the gaps in the literature and devise the focus for the current work. This will also be extended to the non-clinical phenotype of ASC that includes those who do not have ASC but display traits associated with the condition in order to assess the link between ASC and the non-clinical phenotype. The main cognitive theories used to understand ASC will be briefly described in order to help the reader understand the perspectives from which the current work is built.

### Defining Autism Spectrum Conditions (1.1)

Autism Spectrum Condition (ASC) is pervasive developmental condition which affects an individual's ability to engage with and interpret social information alongside a restrictive and repetitive pattern of behavioural routines (APA, 2013). This reflects Kanner's original classification of ASC as "extreme aloneness" which co-occurs with a "preoccupation with the preservation of sameness" (Kanner, 1943; Kanner & Eisenberg, 1956). However, in line with the constantly evolving research landscape assessing the underlying causes and explicit behaviour associated with ASC, the clinical diagnosis of ASC has varied since its conception.

Originally, the diagnostic criteria for ASC was based on three domains derived from the triad of impairments first set out by Wing and Gould (1979). This seminal paper described how the impairments associated with ASC seemed to 'cluster' and co-occur. The triad of impairments consists of difficulties in areas relating to social impairment, communication difficulties and restricted or repetitive areas of interests. The triad was derived from an investigation into 132 children with special educational needs who showed at least one of the three behaviours. It was found that when one difficulty occurred, the others tended to occur alongside. This suggests that the symptoms that underlie autism can co-occur. However, the children selected for this study had general special educational needs and

although some matched Kanner's criteria for autism, not all children were diagnosed with ASC. This research suggests that symptoms of ASC co-occur together even outside of a strict diagnosis, which lends support to a wider spectrum of autism traits that stretches throughout the population.

Following on from this, research has further examined the extent to which the triad of factors relating to ASC co-occur. Recent research reports that although the social aspects of ASC may cluster, the social and non-social domains may be somewhat independent. For example a replication of Wing and Gould (1979) but using a community sample and questionnaire data discovered only a very weak association between the social and non-social elements of ASC (Ronald, Happe, & Plomin, 2005, 2006; Ronald, Happe, Price, Baron-Cohen, & Plomin, 2006). Research such as this suggests that although the social and non-social aspects of autism are integral to the presentation of the disorder, social and non-social deficits may relate to behaviours which are distinct from one another and can vary independently. Further support for this distinction comes from research employ factor analysis in order to assess the extent to which social and non-social aspects of ASC tend to co-occur. This methodology is useful as it suggests that if both the social and non-social aspects of ASC do in fact cluster with each other, they should then load onto a single factor during a factor analysis. Only one research group has found that both the social and non-social impairments load onto one factor using this method (Constantino et al., 2004; Constantino, Przybeck, Friesen, & Todd, 2000; Constantino & Todd, 2000), whereas others have found that triad of impairments could either fall within a single factor, but load onto sub-factors within a primary factor (Bolton et al., 1994) or consist of 2 or more distinct factors that vary independently (Austin, 2005; Hoekstra, Bartels, Cath, & Boomsma, 2008). This would suggest that the clustering and co-occurrence of ASC deficits does not occur in the way that Wing and Gould (1979) originally laid out and instead social and non-social aspects of ASC are likely to vary independently within each individual.

In support off the independence of the social and non-social aspects of ASC, a recent review has suggested that the link between repetitive behaviour and social-communication impairments has been overstated and the underlying and genetic causes of these aspects of ASC could be independent (Mandy & Skuse, 2008). In light of such growing research the criteria in the fifth restructure of the Diagnostic and Statistical Manual (DSM-V; APA, 2013) have been reduced from having 3 areas reflecting the triad of impairments to just two main factors. The new criteria reflects the disassociation between the social and non-social aspects of ASC and is in keeping with a dimensional approach to the disorder.

A dimensional approach suggests that individuals will often vary on the difficulty they display with regard to each factor of a condition and that there is no hard line between what is and is not considered a disorder (Hudziak, Achenbach, Althoff, & Pine, 2007). This allows clinicians to assess an individual's level of severity with regards to individual aspects of ASC. The dimensional approach has been built on overwhelming research support, especially within the area of ASC, which suggests that the spectrum of autism lies on continuum that runs through the general population (Baron-Cohen, Hoekstra, Knickmeyer, & Wheelwright, 2006; Piven, 2001). Individuals who have the most difficulty with their day-to-day functioning will lie at the high end of this spectrum in areas relating to ASC difficulty and will receive a diagnosis. However, there is hypothesised to be individuals who have high traits of ASC who do not have difficulty in their day-to-day lives. These individuals will be explored further with respect to the social deficits of ASC in the current thesis.

The current thesis aims to explore factors that may have an effect on the presentation of social deficits in ASC and the spectrum of ASC-traits present in the general population. This will be studied independent of non-social deficits through exploring cognitive mechanisms of social perception and attention. The presence of the social difficulties associated with autism that are present both in diagnosed ASC and the extent to which traits of ASC are seen in the general population will be explored in order to better understand the spectrum account of ASC.

## **Social and Emotion processing ability in ASC (1.2)**

### *Social processing ability in ASC (1.2.1)*

Studies of social attention in ASC have been able to explicitly show that the mechanisms underlying atypical social behaviour seen in ASC deviate from typical behaviour. The ASC differences in attending to others have been shown to be an early marker of the condition which highlight how integral atypical social processing is to the condition. For example, research examining video tapes from the first year birthday parties of children who were later diagnosed with ASC has shown that affected children did not show the same level of attention towards social interaction attempts made by others as both typically developing and developmentally delayed controls (Osterling & Dawson, 1994; Osterling, Dawson, & Munson, 2002). These studies monitor when an adult tries to capture the attention of a child and interact with them socially. Individuals with ASC were less likely to respond to

social interactions made by adults, even at this early period in life. This suggests that the mechanisms underlying social attention and reciprocation are deficit from an early point in life. Eye-tracking research, which is able to examine what aspects of an environment draw an individual's attention, has found that people with autism show reduced attention towards the core areas of the face (Chawarska & Shic, 2009; Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Pelphrey et al., 2002; Trepagnier, Sebrechts, & Peterson, 2002). Klin et al., (2002) used eye tracking technology while individuals with ASC observed naturalistic social scenes. In this free looking task, it was found that those with ASC were best identified by the amount of time they looked at the eye region of the face while watching social interactions; people with ASC tended to look less at this region. Further to this, looking time towards the mouth varied as a function of symptom severity with greater mouth fixations in this group. This suggests that there is a difference in the way ASC individuals attend to the face which is predictive of their dimensional levels of social ability.

People with ASC have been shown to suffer interference effects from emotional faces when trying to complete a modified version of the stroop task. The modified stroop task uses using 'distractor' faces covered by coloured overlays. The participant is required to name the coloured overlay. Ashwin, Wheelwright and Baron-Cohen (2006) found that compared to control participants, individuals with ASC tended to name the colour of the overlay slower when a face was presented behind it. Control participants only showed this effect for aggressive facial emotion stimuli which would be expected for such important signs of threat. The prevalence for reduced attention for social information coupled with heightened interferences from social information in ASC occurs alongside relatively intact attention for non-social stimuli, at least in children with ASC (Maestro et al., 2005; Maestro et al., 2002). This has been reinforced using attentional-probe studies that have shown that people with autism do not show the same enhanced bias for faces that control groups show when presented with face and non-face stimuli (Moore, Heavey, & Reidy, 2012).

### *Emotion expression processing in ASC (1.2.2)*

Emotional expression research in typical development is based in the seminal work of Ekman (1972). Ekman used a preliterate culture with no knowledge of western culture in order to assess whether there were universally accepted emotional expressions. Tribespeople of Papa New Guinea were asked to look at images of American actors mimicking emotional expressions and try and describe how the person could be feeling or

what may have led to the individual making an expression. The tribespeople were able to indicate a meaning for a selection of emotional expressive faces. For example, when shown an angry expression, people responded that the model's goats were likely stolen or upon seeing a sad expression, participants would indicate that the model's baby had just passed away. Through this work, Ekman was able to show that there are 6 universal expressions which share a common meaning world-wide. These expressions include Happiness, Sadness, Fear, Anger, Surprise and Disgust. The emergence of a common language for emotional expressions suggests that there is an innate ability to recognise the arrangement of core facial information as a social signal.

The clinical features of someone with ASC includes difficulty understanding the intentions and mental states of others through facial expressions (APA, 2013). This suggests that there could be an impairment with the innate ability to recognise the six basic emotional expressions in individuals with ASC. Early research that explored emotion processing in ASC used free labelling, forced choice or matching-to-sample tasks. These tasks required participants to observe an emotional expression displayed in an image or video and then choose a matching pictorial or verbal representation of the expression or name it from memory. Many of the early studies used the six basic emotional expressions discovered by Ekman. Research has found lower levels of emotion recognition ability in ASC across the board when compared to control participants (Harms, 2010). An ASC deficit for emotion expression recognition has been found when compared to age matched controls (Feldman, McGee, Mann, & Strain, 1993; Tantam, Monaghan, Nicholson, & Stirling, 1989), Verbal and non-verbal IQ matched controls (Braverman, Fein, Lucci, & Waterhouse, 1989) and developmental disability controls (Hobson, 1986). The emotion recognition deficit has been seen across both low (Braverman et al., 1989; Celani, Battacchui, & Arcidiacono, 1999; Ozonoff, Pennington, & Rogers, 1990) and high functioning individuals (Braverman et al., 1989; Davies, Bishop, Manstead, & Tantam, 1994; Feldman et al., 1993; Hobson, 1986; Macdonald et al., 1989; Ronald et al., 2005; Tantam et al., 1989; Teunisse & de Gelder, 2001). However, other early studies of emotion expression recognition failed to replicate the reported difficulty in expression recognition in people with ASC finding equal ability between those with ASC and controls (Fein, Lucci, Braverman, & Waterhouse, 1992; Loveland, Pearson, Tunali-Kotoski, Ortegón, & Gibbs, 2001; Loveland et al., 1997) with some suggesting that the only variation is related to within group variation of IQ or ability on false belief tasks (Prior & Hoffmann, 1990).

One of the main advances in emotional expression research in ASC individuals is the understanding that it is possible to recognise some emotional expressions and not others. Some studies were able to show partial replication for certain emotional expressions but not others. For example, when compared to happy and sad emotional expressions, children with ASC are less able to correctly label surprised expressions. This is suggested to arise from surprise being more complex than other emotions as context often makes a large difference to the understanding of surprise (Baron-Cohen, Spitz, & Cross, 1993; Baron-Cohen, Wheelwright, & Jolliffe, 1997; Bormann-Kischkel, Vilsmeier, & Baude, 1995). In addition to this, people with ASC have been found to be worse at negative emotion expressions such as anger and fear (Ashwin, Chapman, Colle, & Baron-Cohen, 2006). Following the discovery of emotion processing difficulties in ASC, and that some emotions are recognised better than others, studies started to investigate the exact limitations on emotion processing in ASC. By assessing the exact conditions that facilitate and impair emotion processing in ASC, research can start to understand the underlying mechanisms that are involved with the impairment. For this reason, Aspects such as presentation timing and the perceptual strength of the emotional expression being presented were manipulated. For example, the first study use restricted presentation timing to assess emotion recognition difficulties in ASC was a typical match-to-sample paradigm, but only allowed 750ms of exposure to the target expression (Celani et al., 1999). Prior to Celani et al., (1999), studies had allowed unlimited viewing time of emotional expression stimuli. In a traditional match to sample technique, participants generally are shown a target image of an emotional expression alongside several sample images that they are encouraged to find the matching emotional expression from. Such studies often have the presentation stimuli and sample stimuli appear concurrently. This means that individuals could potentially complete the task without having to understand the emotional expression. Instead participants can rely on low level processing such as shapes and lines in order to choose the correct and matching sample image. Emotional expressions do not have an unlimited viewing time, they are quick and fluid in nature (Damasio, 2008; Ekman, 2003). Using a restricted time frame through which to display the emotional expression is more representative of the fleeting emotions encountered on a day to day basis. Celiani et al., (1999) showed that when time constraints are placed upon the viewing of the target emotional expression, ASC individual's accuracy for recognising emotions is much lower than typically developed and learning disabled controls. This suggests that whatever strategies used for decoding emotional expressions in people with autism (i.e. piecemeal

processing; Shah & Frith, 1993) fails when time constraints added to the task. This study was important for the emotion processing literature as emotional expressions are, by their nature, fleeting and transient. Through using tasks that only allow participants a limited exposure to stimuli, we are better able to study effects such as emotion processing in a way that is much more representative of the transient nature of the social world.

Barring Celani et al., (1999), many early studies displayed stimuli for prolonged periods of time. For example, in most of the early emotion processing research, emotion expression stimuli were available to participants to view for an unlimited amount of time. In addition to this, one issue present in most of the above studies, however, is that they employ facial emotion expression stimuli that show extreme, full-blown expressions posed by actors. Such stimuli do not have the subtleties of emotional expressions seen in day-to-day life. More recent studies have acknowledged the subtlety and transient nature of emotional expressions and devised stimuli that reflect this. Such studies using a forced choice paradigm have shown that people with ASC find it difficult to perceive milder representations of some negative emotional expressions. For example, one study required ASC and control individuals to judge videos that showed actors expressing mild emotional expressions. These videos always started at neutral and then progressed a set level of expression strength (from 20% - 100%). The researchers found that for negative expressions (anger, surprise and disgust), participants with ASC performed worse than controls at milder representations of the expression (Law Smith, Montagne, Perrett, Gill, & Gallagher, 2010). This suggests that those with ASC need more expressional information in order to recognise an emotion. With less information the emotion expressions of others are less interpretable for those with ASC. A similar result has also been found for all basic emotions when using static subtle images rather than videos (Wong, Beidel, Sarver, & Sims, 2012). In addition to this, people with ASC have been shown to need a greater amount of expression information in order to be able to make accurate judgements (Bal et al., 2010). Bal et al., showed children with ASC faces that morphed from a neutral face to an emotional expression while measuring eye fixations. This work showed that children with ASC took longer to identify the emotion (and therefore used more emotional information) and ASC expression recognition ability was correlated with the time spent looking at the eye region of the face. This suggests that people with ASC may be able to understand an emotional expression with enough social-emotional information, but when limits are placed on this information the task of identifying emotional expressions becomes untenable. One reason that mild expressions could be difficult for ASC individuals is that



they require more information in order to correctly represent facial emotions in cognition. This research suggests that there could be an issue with the ability to represent emotional expressions in cognition in ASC, something that has received little research attention.

Imaging studies have moved the field forward by being able to assess the differences in ASC emotion processing ability on a brain based level. Brain imaging research is able to measure the structural differences and functional activity in areas of the brain. This has proved useful in highlighting brain based differences in emotion recognition in people with ASC (Harms, Martin, & Wallace, 2010). One reason why brain imaging techniques are helpful is because neuroimaging techniques are less susceptible and more sensitive to the utilisation of compensatory strategies. Compensatory strategies, which are used as an alternate way to complete any given task, tend to use brain regions that are unexpected for the given task. fMRI studies have been used to explore emotion expression processing in the social brain, a collection of brain regions that reaction to social stimuli including the amygdala, the pSTS, the FFG and the mPFC (Dunbar, 1998). During fMRI studies, the brain is imaged either during exposure to, or identification of, emotional expression stimuli. In general people with ASC show differential activation of the social brain and even activation in areas outside of the social brain network in response to emotional faces than do control participants. For example, Klinhans et al., (2011) presented ASC and control participants with fearful expressions and neutral stimuli while undergoing fMRI scanning. The researchers recorded less activation in subcortical structures of the brain, such as the amygdala and fusiform gyrus, in response to fearful expressions. These structures have been linked with face processing (Kanwisher, McDermott, & Chun, 1997; Adolphs, Tranel, Damasio, & Damasio, 1995; Calder, 1996), implicit and automatic emotion processing (Damasio, 2008) and attention towards emotionally salient aspects of the environment (Calder, Lawrence, & Young, 2001). Reduced activation in these areas could mean that those with ASC do not engage with emotional expression stimuli in their environment in the same way as typical controls, perhaps leading to a reduced experience with emotional faces that lead to later emotion processing issues. However, although the results from Klinhaus et al., (2011) inform about subcortical differences in ASC, the nature of these differences are hard to interpret. As suggested above, facial emotion expressions are rarely seen as explicit expressions. Instead they are displayed along a continuum from neutral, through mild to extreme depending on the situation. This scaling of information would typically allow for the viewer to moderate their response. For example, a mild fearful face may not represent the immediacy of danger as much as an extreme fearful face. To

understand this further in ASC, Ashwin, Baron-Cohen, Wheelwright, O'Riordan, and Bullmore (2007) required ASC participants and non-ASC controls to view neutral, mild fearful and extreme fearful faces while undergoing brain imaging. The results showed that in control participants amygdala activation varied in response to the different levels of fearful stimuli. Those with ASC, however, did not show varying levels of activation in response to fearful faces and showed different patterns of activation more generally. Overall, the evidence for abnormalities in subcortical regions of the brain in ASC is well supported. The results from Kleinhaus et al., and Ashwin et al., have since been suggested to arise from issues with the connections between the amygdala and other subcortical areas. For example, using functional connectivity techniques which use fMRI to map the connections or pathways between brain areas, reduced functional connectivity between the amygdala and the fusiform face area has been reported for participants with ASC (Kleinhaus et al., 2008). In addition to this, even when amygdala activation is seen in ASC, the efferent connections from the amygdala have been reported to be diminished (Hall, Doyle, Goldberg, West, & Szatmari, 2010). Neuro imaging evidence helps to support the difficulties expressed by those with ASC when recognising emotional expressions, suggesting that atypical subcortical function and connections could play a role in the development of atypical social behaviour. This can be explored on a cognitive level using paradigms that assess the mechanisms associated with these neural functions.

### **The Spectrum of Autism Traits (1.3)**

#### *Broader Autism Phenotype (1.3.1)*

The spectrum approach to ASC originally arose from work assessing the immediate family of individuals with ASC. In an attempt to assess the heritability of ASC, Folstein and Rutter (1977) examined 21 pairs of twins, of which one of each pair held an ASC diagnosis. Through their analysis to understand the heritability of autism, they devised an assessment of broader cognitive impairments that were reflective of those found in ASC. When assessing siblings of ASC individuals, Folstein and Rutter found the presence of associated, but milder, cognitive difficulties in twin siblings that were reflective of those displayed by ASC individuals. This discourse set the scene for investigating what was then known as the broader autism phenotype (BAP) which was evident in relatives of individuals with ASC as a cognitive phenotype with mild and non-clinical symptomology of ASC.

However, research that assessed the presence of ASC-like cognitive deficits in immediate relatives of those with a diagnosis did not show consistent support. For example, Freeman et al. (1989) found no correlation between ASC individuals and the non-ASC probands and parents on measures of cognitive function including verbal and non-verbal IQ and the Wide Range Achievement test, which assesses general cognitive word reading and understanding. In addition, the same study compared parents and siblings scores to published norms finding no difference in cognitive ability. This was echoed by Szatmari et al. (1993) who showed that there were also no differences in cognitive behaviour scores. Szatmari et al., went further by assessing social-communicative impairments, also finding no difference compared to control groups of parents and siblings of downs syndrome and low birth weight individuals.

The early studies that were unable to support the notion of the BAP assessed both cognitive and social differences against published norms or against specified groups of control individuals. As suggested above, the social and non-social aspects may not co-occur regularly in those diagnosed with ASC. Some of the null findings relating to the BAP are likely explained as the authors aimed to assess both social and non-social aspects, in a milder form, in non-ASC individuals. In addition to this, the differences are not explicit enough to warrant concern and would not occur at the level of atypical behaviour seen in ASC. Instead, it would be expected that these subtle differences would manifest themselves as such; subtle nuances in behaviour. Therefore comparing relatives of ASC individuals to ASC behaviour was a methodological limitation in many of the early studies.

These limitations were addressed by Wolff, Narayan, and Moyes (1988). Rather than assessing parents against published norms or to a control group of ASC individuals Wolff et al., assessed parents of individuals with ASC and non ASC parent controls for personality traits associated with autism while blind to the child's diagnosis. Parents of ASC individuals were found to be less emotionally responsive, lack empathy and show odd social communication. In support of this, Piven et al. (1994) found that parents of people with ASC were rated to be more aloof, untactful and unresponsive to others than control parents. Further, the degree of familial ASC incidence also impacts upon the level of ASC-like traits apparent in non-ASC relatives. Non-affected individuals in families that have more than one incidence of ASC have much higher rates of social communication issues than non-affected individuals from families with downs syndrome relatives (Piven, Palmer, Jacobi, Childress, & Arndt, 1997). Even when assessing behavioural indicators such as emotion and social ability, it has been shown that undiagnosed siblings of people with ASC

reciprocate fewer emotional expressions and show less initiation of joint attention than siblings of individuals without an autism diagnosis (Cassel et al., 2007).

The most extraordinary evidence in support of the BAP comes from experimental studies that assess physiological and attention based differences which typify the disorder in the relatives of individuals with ASC. When such measures are explored with the intent of assessing what extent they are similar to those with ASC, a very concrete link between ASC and the BAP is established. The mild behavioural phenotype found in relatives of ASC individuals includes mild differences in social attention and social reciprocity (Cassel et al., 2007). This is indicative of brain based attention mechanisms that are abnormal in those with an ASC sibling. This difference has been explored on a neuropsychological level using ERP signals that are sensitive to the referential aspects of gaze. Referential gaze is a vital social signal that indicates when another individual is initiating (or attempting to initiate) social interaction or delivering their intention (Senju, Johnson, & Csibra, 2006). Research by Elsabbagh, Volein, Csibra, et al. (2009) showed atypical ERP signals in siblings of individuals diagnosed with autism in response to direct gaze, which is by its nature referential. Elsabbagh et al., found no group differences to averted gaze. This research shows that there are brain based anomalies in BAP individuals that are indicative of the difficulties associated with ASC.

This research helps to reinforce that there is a broader spectrum of autism which extends outside of those who have a firm diagnosis of ASC, especially when considering the social aspects of the disorder. Research assessing the BAP offers support for the potential of a genetic underpinning to the disorder. However, this point should not be overstated as these families were cohabiting. There could be an effect of social learning of ASC-like behaviours in a family context that confounds this interpretation. However, the identification of differences in brain based mechanisms for social attention in BAP individuals that are similar to what would be expected in ASC helps to counter this point. Regardless, the evidence that a phenotype that is associated with a milder expression of ASC has led to the identification of this outside of the relatives of people with ASC.

### *The Wider Autism Spectrum (1.3.2)*

More recently research has explored the extent to which traits of autism could be present on a wider scale that differs and varies in throughout the entire population. The presence

of a continuum of autism traits that runs through the general population will be referred to as the Wider Autism Spectrum (WAS). The WAS by definition contains within its continuum the BAP. However, BAP individuals would be expected to lie at the higher end of the WAS. Baron-Cohen, Wheelwright, Skinner, Martin, and Clubley (2001) assessed the traits of autism in the general population through the use of a 50-item questionnaire known as the autism quotient (AQ). The AQ measures traits of ASC through the use of a self-report questionnaire which presents participants with statements relating to behaviours and thoughts which are representative of those found in individuals with ASC. In a validation study with 4 groups of respondents (ASC, general population, student sample, mathematicians), all populations varied to the extent of ASC-traits that they displayed. However, although there was population variation amongst responders the AQ could discriminate 80% of those with ASC from those without ASC. In addition to this, twice as many male than female participants obtained 'intermediate' scores of 20+ reflecting both the male biased gender split in autism and supporting the extreme male brain theory of autism (Baron-Cohen et al., 2001). This shows a link between traits of ASC in the general population and how these link to the condition of autism.

Developing from the creation of the AQ as a screening tool, research has aimed to assess the extent to which AQ can be used as a research tool to explore the WAS and how the WAS relates to ASC both behaviourally and biologically. Findings reflecting those presented in BAP individuals regarding the difficulties in social-emotional processing and atypical social attention have also been reported in the individuals from the WAS who display a high degree of autism traits. As suggested above, the social and non-social aspects relating to ASC seem to be relatively distinct. Non-social aspects associated with ASC have been found across the WAS. For example, Stewart, Watson, Allcock, and Yaqoob (2009) found that people with high AQ were able to complete the block design task more quickly than those with a lower AQ which has also been shown to occur in ASC. Other findings have supported that people with high AQ have a cognitive processing style similar to that seen in ASC. For example, high ASC-like traits as measured by the AQ predict visuospatial ability which is enhanced in ASC, but not verbal-analytic ability (Fugard, Stewart, & Stenning, 2011). Although one recent study found no link between AQ and performance on a host of working memory tests (Maes, Vissers, Egger, & Eling, 2013), this study reported the results from only 38 participants, whereas other studies that acknowledge that more participants are necessary in order to detect ASC like behaviours in a mild form have been able to show an effect of autism traits on a host of tasks relating to working memory performance that

are reminiscent of both the difficulties and advantages seen in ASC (Richmond, Thorpe, Berryhill, Klugman, & Olson, 2013). This thesis is concerned with understanding the social aspects of ASC and the WAS. This will be explored further in the remainder of the chapter.

## **Social and Emotion processing ability in the WAS (1.4)**

### *Social ability variation in the WAS (1.4.1)*

The AQ has been found to highlight difficulties spanning the domains of social-cognitive impairment evident in ASC. For example, undiagnosed people with a high number of ASC-traits show an atypical gaze cuing effect when compared to those with fewer autism traits (Bayliss & Tipper, 2005). Bayliss and Tipper required individuals to respond to a target which appeared on either the left or right hand side of the screen. On some trials, social stimuli (faces) were presented on either side of the screen and a cue preceded a target on one face or the other. Other trials used non-social stimuli (scrambled faces). The appearance of the target was cued either by an arrow or by eye gaze. The results found that people with high autism traits were able to show a gaze cueing effect to scrambled faces, but not whole, unscrambled faces, whereas low trait individuals showed the reverse effect. However, this does not necessarily mean that high ASC-trait individuals have a processing style that favours non-social stimuli. In a second study, the authors replaced the face stimuli with tools. The drive to systemise seen in people with ASC suggests that high autism trait individuals may be more readily cued by systemising objects such as tools. However, it was found that the high AQ participants still showed a large cueing effect toward the scrambled object rather than the whole unscrambled tool. This suggests that atypical attention across the WAS isn't necessarily reflective of purely social issues indicative of ASC. Instead attention differences could reflect the increased attention to detail shown by ASC individuals.

However, this atypical basis for attention could lead onto atypical social behaviour, even across the WAS. High ASC-trait individuals do not show the typical preference for direct versus averted gaze which is evident in people with fewer autism traits (Chen & Yoon, 2011). Even when applied to more realistic conditions such as during video-based interactions, people with greater ASC-traits look less at the face of an experimenter. This does not seem to translate to actual real-world interactions where no such differences were reported (Freeth, Foulsham, & Kingstone, 2013). This could reflect that the

participants are in the WAS and do not have a diagnosis of autism and are, therefore, have found compensatory ways in order to exist in normal and functional lives without requiring support. These studies reveal that differences and variations in attention and how people from the WAS with a high degree of ASC-traits attend to social information. Furthermore, these atypicalities are similar to the differences in social attention in people diagnosed with ASC and reflect these differences throughout the WAS.

The impact of atypical social attention can be seen in studies that probe the social capacity of people against their level of ASC-traits. For example, during a cueing paradigm that involved social learning, where participants were expected to learn that anti-social targets offer unreliable cues, people with high ASC-traits were not able to learn this association whereas low ASC-trait individuals were (Hudson, Nijboer, & Jellema, 2012). This shows that persistent issues that this group have with social stimuli may lead to impairments when it comes to trying to gain insight into the meaning of others' dispositions.

Social attention differences have similarly been linked to physiological and neural variation throughout the WAS. A study by von dem Hagen et al. (2011) showed both differences in white matter volume between high and low ASC-trait individuals and in BOLD response to the stroop task in areas adjacent to the pSTS) The pSTS is implicated in processing socially relevant information and has been suggested to have a resting state that is relatively active. The activity in the pSTS reflects the possibility of a system that is continually processing possible social information. This difference seen in those with High ASC-traits in this study was particularly interesting as typically, during cognitive tasks such as the stroop, this area "deactivates" to a certain extent. The deactivation has been thought to reflect the brains conscious effect to switch from interpreting social information to instead focusing on the cognitive task at hand (Gusnard & Raichle, 2001; Mazoyer et al., 2001; Shulman et al., 1997). In ASC (Kennedy, Redcay, & Courchesne, 2006) and high ASC-trait individuals (von dem Hagen et al., 2011), the limited deactivation of this area may suggest that its resting state is lower than that of typical individuals and those with low ASC-traits. As such, this area may not be continually processing social information in the same way as the typical brain.

Further to this, the activation of the amygdala and other areas of the social brain has been shown to vary in response to direct eye gaze depending on the traits of ASC an individual possesses (Hasegawa et al., 2013; Nummenmaa, Engell, von dem Hagen, Henson, & Calder, 2011). The reward circuitry of the brain has been found to show less activation in response

to social reward (social reinforcement), but not non-social reward (money), in people with high versus low empathetic ability (Gossen et al., 2013); a construct closely linked with ASC. These studies strongly tie the neural functioning and structure of the brain to the WAS. A large body of evidence therefore exists for functional and structural neurological differences that relate people with high ASC-traits to those with ASC. This offers significant support for the cognitive phenotype of the WAS having a neurological basis, which can be explored through psychological paradigms.

#### *Emotion expression processing in the WAS (1.4.2)*

Emotion expression understanding has been under-researched with respect to the WAS thus far. Perlman et al. (2009) have shown that personality traits can affect the visual scanning of emotional faces. In this study, self-reported neuroticism score predicted the amount of time participants spent looking at the eye region of the face. As neuroticism is positively correlates with AQ (Wakabayashi, Baron-Cohen, & Wheelwright, 2006), it is likely that similar differences in emotional expression processes exist across the WAS. The behavioural recognition work that has been completed in this area has started to show a promising link between the number of autism traits an individual possesses and their ability to process emotional expressions. For example, (Li & Tottenham, 2013) found that people with high ASC-traits were performed worse when identifying emotional expressions of others compared to controls. Interestingly, however, these individuals were no less accurate than control at identifying their own emotional expressions, an ability that has been found to be impaired in ASC individuals. This might suggest a perceptual disassociation between self vs. other perception in those at the high end of the WAS. Further to this, one large study, conducted with 500 typically developing individuals, found that people with more traits of ASC were not only less likely to accurately identify negative emotions (anger, disgust and sadness), but even when their judgements were correct, they needed a greater amount of emotional information in order to make such judgements (Poljac, Poljac, & Wagemans, 2013). Through understanding the extent of the emotion processing deficits present in high trait WAS individuals, research such as Li and Tottenham and Poljac et al., allow us to understand where the high end of the typically developing WAS ends and a diagnosis of ASC begins.

Fear is one emotion that has been shown to be processed atypically in those with ASC. Individuals with ASC tend to make errors when judging fearful expressions and as seen



above, there is less activation of the amygdala and other subcortical brain regions when viewing fearful faces (Ashwin et al., 2007; Kleinhans et al., 2011). Although the same tendency has not been directly replicated in those with high ASC-traits, Miu, Pana, and Avram (2012) found that high ASC-trait participants did not show the expected attention bias for fearful faces that those with fewer traits displayed. Additionally those with high ASC-traits were found to have atypical and *enhanced* fear conditioning. This suggests that the mechanisms guiding attention for emotional stimuli could be also be atypical at the high trait end of the WAS. Note, however, that the high ASC-trait group in this study showed enhanced fear conditioning which, although in-line with the research in people with ASC (Bernier, Dawson, Panagiotides, & Webb, 2005; Gaigg & Bowler, 2007), is one that can only really be explained through the use of employed compensatory strategies, of which the underlying mechanisms are, as of yet, poorly understood.

There may be differences in the neural networks underlying emotion perception across individuals in the WAS in a similar way to that expressed in ASC. Although no one study has shown explicit differences in brain response in response to emotional expression stimuli, one study examining the mirror neuron system has been able to suggest abnormal neural function for this ability. In a study of typically developing individuals, N. R. Cooper, Simpson, Till, Simmons, and Puzzo (2013) used a classic mirror neuron research technique which involved showing participants a video of a model opening and closing their hand. Typically, it would be expected that a certain pattern of electrophysiological activity would be found relating to the sensory motor regions that code for the observation and action of this motion. The novel twist to this study was that during each trial, the model in the video made either a happy, angry or neutral expression. The study reported electrophysiological differences between high and low ASC-trait groups in the sensory motor areas of the brain during trials containing an emotionally expressive actor. This not only suggests that emotion processing differences exist in the general population based on traits of ASC, but also that emotion processing differences can have an impact on multiple networks in the brain, such as the sensory motor system.

The differences seen in high and low ASC-trait individuals could be explained by theories that attempt to explain ASC. For example, in an examination of the extreme male brain theory of autism, which closely related to the E-S theory, Vladeanu, Monteith-Hodge, and Bourne (2012) used a hemispheric lateralisation task, where two competing visual stimuli are presented to each hemisphere of the brain. One of the premises of the extreme male brain theory of autism is that people with autism may have been subject to greater levels

or prenatal testosterone levels, and owing to this their brain will develop atypically. One such feature of prenatal testosterone is that it encourages development of the right hemisphere meaning that these people would be expected to show an increased right hemispheric lateralisation. By measuring which stimuli appears more prominent to the participant, lateralisation tasks are able to detect which hemisphere is responsible for processing the presented information. The authors found that males with high ASC-traits (especially those relating to an aloof personality) were more likely to be strongly right-lateralised with regards to processing expressions of fear, surprise and happiness. This evidence shows how differences in brain lateralisation in autism can be represented along a continuum of typical development. This shows that differences in emotion processing which relate to differences in the brain can be seen in the WAS. However, a further test of lateralisation did not find such strong lateralisation in a sample of individuals with high autism traits when assessing cheek bias in photos of others displaying emotion (Harris & Lindell, 2011), though this task used purely images of happy expressions, which people with autism and those with high autism traits have not reliably been shown have impairments with which could cause this study to lack the sensitivity required to detect such a bias.

### **Relevant theories of autism (1.5)**

As seen above, the theories that attempt to explain ASC are important when understanding the results that may arise from studies of emotion expression processing and how these results relate to the disorder as a whole. This section will explain several of the key theories present in the autism literature, present evidence that support the theories explanatory power and discuss the limitations of the theories with regards to the current topic.

#### *Weak Central Coherence (WCC) account (1.5.1)*

The WCC account suggests that both impairments and relative strengths seen in people with autism relate to a processing style that people with the disorder use to process the world around them. Typical central coherence is a processing style where people are able to extract information from the world as a complete whole (global processing style); in order to get the overall importance (or the gist) from all the parts that make up a situation. Under a global processing style an individual would be able to understand and process the world at a conceptual level. An example of this would be the ability to appreciate a group of trees that are situated in one area as a complete woodland. Frith and Happé (1994) put forward the notion that people with ASC have a processing style with a weak central coherence, meaning that ASC individuals are more likely to pick up on the smaller details

within an environment at the expense of the bigger, overall whole (local processing style). Applying the earlier example here, people with ASC may miss the concept of a 'wood' for all the trees which they perceive as individual elements.

Classic research in support of this theory used cognitive perceptual tests such as the block design and embedded figures task. The block design task presents participants with several cubes which have either white face, red faces or faces which are both red and white. Participants are then shown a simple geometric shape which can be made out of a combination of 9 or 16 of such cubes and are then required to recreate the shape. Shah and Frith (1993) found that individuals ASC were able to complete this task more quickly than typically developing and IQ matched controls. This was taken as evidence that the cognitive processes style of ASC individuals may act in such a way that they perceive the target image as a product of its parts rather than a gestalt whole. Seeing the detail in an image is an indicator of a local processing style and therefore supports the notion that ASC individuals may naturally adopt this style. Further to this, it was found that people with autism were able to complete an embedded figures task more quickly and with more success than those without autism (Shah & Frith, 1983). During this task, the goal is to find independent shapes within a complete picture such as the number of triangles present within a hand drawn image of a pram, and it is a marker of people with ASC being able to free themselves of the field dependence associated with a global processing style, and not automatically viewing the image as a consistent whole.

With regards to the social processing deficit in ASC, difficulty could arise if affected individuals are processing social stimuli such as faces by over focussing on independent parts rather than the complete whole. Eye-tracking research suggests that the mouth is attended to preferentially over the eye region in this cohort. For example a classic study by Klin, Jones, Schultz, Volkmar, & Cohen (2002) utilised eye tracking technology while individuals with ASC observed naturalistic social scenes to shown that people with ASC tend to have an atypical face viewing pattern. This pattern reflected that people with ASC attend to the mouth region of the face more than those without ASC and have reduced eye fixations. This suggests that there is a difference in the way ASC individuals process the face, but by processing the faces core features independently those with ASC can select the information that is most meaningful to them. For example, it may be that the mouth region helps to convey explicit and concrete meaning to individuals with ASC such as language and this could be more meaningful than the social information conveyed by the eye region (maybe cite the eyes task). However, face processing style can be explained as a product of

weak central coherence. This suggests that ASC individuals do not have a typical face processing style and instead tend to over focus on specific regions to the overall detriment of their social ability. Further studies have shown that a penchant for local processing of faces, which leads to over focussing particular regions of the face such as the mouth and under focussing on others such as the eyes, has been seen in ASC children as young as 2 years of age (Jones, Carr, & Klin, 2008). However, it is important to note that this isn't a homogenous behaviour that can be attributed across ASC. Many aberrant gaze styles have been documented, such as over focussing on objects rather than faces (Jones, Carr, & Klin, 2008; Rice, Moriuchi, Jones, & Klin, 2012). Not all of these can be solely explained by weak central coherence as there are potentially other deficits that are driving this impairment such as differences in social-attention. In addition, a review of the eye tracking literature shows that although there is support for an aberrant face processing style in ASC, the support for excess mouth and reduced eye fixation is not wholly supported. Instead a general aberrant face gaze profile has been found in those with ASC (Falck-Ytter & von Hofsten, 2011).

The drive to over focus on *any* one aspect of the face, as suggested by the WCC account, could mean that this group miss valuable social information. Evidence for this came from Lopez, Donnelly, Hadwin, and Leekam (2004) who presented participants with and without autism an image of a face prior to showing them a facial feature (eyes or mouth). They then asked participants whether the feature was the same as the one that belonged to the model they had seen previously. Some trials were cued, in that the participant was told which feature to focus their attention on during presentation of the first image. Lopez et al., found that people with ASC were much more able to successfully indicate whether the feature belonged to the model on cued rather more often than on non-cued trials. Participants without ASC were better able to judge whether the feature belonged to the model regardless of cue. This supports that idea that WCC in ASC could prevent people with ASC from being able to attend to the whole face and will subsequently miss relevant social information. Further to this, another study limited the ability to use local processing by presenting participants with low spatial frequency filtered images of emotional expressions (Katsyri, Saalasti, Tiippana, von Wendt, & Sams, 2008). Low spatial frequency filters blur an image so that the individual features become less distinct and the image is better interpreted based on the gestalt whole rather than a local processing style. Katsyri et al., found that once images of emotional expressions had been passed through a low spatial frequency filter, the ability of ASC participants to recognise emotional expressions

declined radically. This research suggests that people with ASC may be using a local processing style in their day to day social interactions in order to make judgements from small pieces of information rather than an overall whole. This could potentially limit their ability to glean necessary information from socially relevant stimuli and lead to some of the social impairments seen in this group.

However, although people with ASC may have a drive to process detail by default, they have been shown to process globally when necessary (Mottron, Burack et al., 1999; Ozonoff et al., 1994; Plaisted et al., 1999). A study by Mottron, Burack, Larocci, Belleville & Enns (2003) which aimed to dissect this used several tasks which involved both local and global processing. While the ASC group showed superior performance on tasks where a detail focussed processing strategy was advantageous compared to age and IQ matched controls, on tasks that required a global processing style, there were no differences in ability. This suggests that although a local processing style may be superior to global processing in ASC there may not be a deficit with central coherence leads to an inability to process in a global manner.

#### *Empathising-Systemising theory of autism (1.5.2)*

The WCC account was able to explain some of the features of ASC as a product of the inability to have a global processing style. This approach applies when assessing some of the deficits seen in ASC, however as shown above hypothesised inability to process globally is not wholly supported by research. Instead, it is suggested that people with ASC can in fact use a global processing style, but have a preference for local processing.

A local processing style can be advantageous. By focussing in on the details of a given system, the predictable elements of the system can be understood better. This approach works very well for natural systems (i.e. weather), mechanical systems (i.e. an engine), mathematical or numeric systems (i.e. calendars) or kinetic systems (i.e. body movement such as hand flapping and rocking, jumping on a trampoline etc). In each of these systems, breaking it down into its components will lead to a relatively accurate prediction of the outcome. However, there are other systems that are less predictable. In such systems the outcome may not directly relate to the input of the system, the input may lead to several outputs, the output could be caused by one of several inputs or the details of the system are simply unobservable and instead have to be derived from inference. When confronted with such systems, a preference for processing the details in order to understand the whole system is no longer an advantageous and could lead to confusion

Social systems are an example of systems that are not predictive in a linear and causal way. These systems include social interaction. During social interactions no input can be isolated to its local parts and instead a combination of many inputs will lead to a variation of different outputs. For example, during a social interaction the words used, the tone of voice, the body language, the previous interactions between the subjects, the context which the interaction takes place, underlying hormonal or other biological responses and the disposition of each of the subjects will all have an input into the interaction. The output of the interaction is necessarily derived from all these inputs (and likely a host more), however may not be derived in any way that is predictable in the same way that a mechanical system is predictable.

In addition to the evidence presented above showing a preference for a local processing style that is useful when understanding systems, people with ASC have been shown to have an enhanced ability to understand predictable systems. For example children with ASC often outperform their peers and older children when solving physics-based problems that have a predictable outcome (Baron-Cohen, Wheelwright & Scahill et al., 2003). Further to this, participants with ASC have been shown to be poor at tests that assess their ability to understand the mental states and intentions of others. These two skills are thought to represent the domains of folk-physics and folk-psychology. The term folk as it is used here refers to an innate and unlearned understanding. Folk-physics is an understanding that refers to the working of systems and folk-psychology is an understanding of people and their underlying intentions and beliefs.

The idea that ASC could be a condition that's defined by a combination of high levels of folk-physics and low folk-psychology is a founding principle of the E-S theory. The E-S theory lays out that all individuals vary to the degree to which they empathise and systemise. The theory defines empathising as the ability to understand and interpret the feelings and behaviours of others and the ability to react in an appropriate way. Systemising on the other hand is an individual's ability to understand how a system operates by assessing how the system inputs relate to the system output. The E-S theory suggests that people with autism will have a disparity between the level that they systemise and empathise in that their systemising ability will far outweigh their empathising ability. Indeed, self-reported preferences for systemising measured using the Systemising Quotient (SQ) show that individuals with ASC report a stronger urge to systemise than do those without ASC and a large discrepancy between empathising and

systemising drive have been reported in those with ASC that isn't found in the majority of non-ASC individuals (Baron-Cohen et al., 2004).

The E-S theory builds off the promising aspects of WCC by identifying what was considered a deficit in ASC (i.e. the inability to focus on the whole) and showing that it is an ability on the extreme end of a continuum of normal functioning. The E-S theory appreciates attention to detail in ASC, but rather than framing it as a difficulty with attending to or understanding the whole, E-S theory suggests that people with ASC are using their strengths at understanding systems in order to identify individual input elements and monitor their effect on the system. An extreme attention to detail in this context is helping those with ASC understand the systems around them. This, therefore, means that whereas the WCC account would suggest that those with ASC will never achieve a coherent and global understanding, the E-S theory suggests that those with ASC could understand the complete workings of the system through observations and control of the many variables that create it.

E-S theory also suggests that the difficulty with social interactions arise through a preference to analyse situations in a rules based manner paired with a low drive and ability in empathising. People with ASC perform particularly low on the Empathising Quotient (EQ) compared to typical controls, suggesting a low drive, and a lack of ability, to empathise.

#### *The amygdala theory of autism (1.5.3)*

The E-S theory described above arose from the work that showed that there may be differences in the substrate of the brain that is implicated in social-emotional processing; the amygdala. The amygdala has been shown to play a key role in understanding emotional expression stimuli and responding to threat based information in the environment. Damage in this brain region leaves individuals unable to judge emotion expressions accurately (Adolphs, Tranel, Damasio, & Damasio, 1995; Calder, 1996; Adolphs et al., 1999; Anderson & Phelps, 2000). When the amygdala is ablated in rhesus macaques, they become socially isolated and no longer respond appropriately to the social interactions of conspecifics (Kling & Brothers, 1992; Kling & Steklis, 1976).

Baron-Cohen et al., (2000) noted the similarities between behaviours that manifest following amygdala damage and the behaviours typically seen in people with ASC. In support of this, it was shown that post-mortem studies and MRI studies commonly find differences in the makeup of the amygdala in those with ASC. For example, post-mortem

studies have shown increased cell density in the amygdala for deceased individuals with ASC (Bauman, Kemper, 1994) and MRI data shows reduced overall amygdala volume in those with the condition (Abell et al., 1999). Further to this, research assessing the amygdala response to emotional faces has since shown that there is reduced activity in this region when people with ASC are viewing fearful emotional expression (Ashwin, Baron-Cohen, Wheelwright, O’Riordan & Bullmore, 2007).

Despite the support for the amygdala theory, there are elements of the disorder it does not account for. For example, the evidence presented above to support the WCC account is hard to understand when taking the amygdala theory perspective. This led to the conclusion that, although the amygdala is likely to be an important brain structure whose function is likely to be impaired in ASC, it is probably only one part of a wider picture. The social motivation theory of autism, to be discussed next, builds upon the research that contributed to the amygdala theory and other theories mentioned above, and builds a more cohesive explanation of the difficulties seen in ASC and how they could occur from the very earliest points in development.

#### *The social motivation theory of ASC (1.5.4)*

The social motivation theory (Chevallier, Kohls, Troiani, Brodtkin, & Schultz, 2012) suggests that individuals with ASC have low social motivation driven by biological differences in substrates such as the amygdala and the reward system. Due to atypicalities in these brain structures ASC individuals are thought to have less drive to attend to social stimuli in their environments and less drive to reciprocate social interactions due to not finding them as rewarding as neurotypical individuals. This is thought to lead to a lack of motivation for rich and engaged social interaction from a young age. The social motivational theory suggests that engaged social interaction with others is a necessary two way relationship that allows for the development of brain structures that aid the development of proficient social perception and cognition. The social motivation theory is designed to explain the basis of social cognitive impairments in ASC. People with ASC do not naturally engage in social reciprocation and therefore develop later deficits in social cognition.

The social motivation theory builds off social attention and drive in typical development. In typical development, from a young age, children are seen to attend to human faces and notice change in human faces more readily than non-human objects. For example, when shown scrambled images and pictures of human faces, infants show a preference to attend to the human face (Gliga, Elsabbagh, Andravizou, & Johnson, 2009; Salva, Farroni, Regolin,



Vallortigara, & Johnson, 2011). Behaviours relating to social orienting and drive have been shown on a brain basis. As stated previously, the amygdala has been shown to guide social attention (Adolphs & Spezio, 2006) and update the attention value of social stimuli (Klein, Shepherd, & Platt, 2009). Other regions have been seen to be capable of learning about social stimuli such as faces (Kanwisher et al., 1997). Further, reward systems in the brain perpetuate the cycle of social interaction by activating in response to social interactions and adding reward value to such behaviour (Izuma, Saito, & Sadato, 2010; Lin, Adolphs, & Rangel, 2012; Tabibnia & Lieberman, 2007). It is suggested that brain regions tuned for social processing work in symphony in typical development to foster an environment where early social attention its reciprocation are rewarding and therefore sustained. This sustained social interaction provides rich feedback and experience to the brain regions associated with them which allows for the fine tuning of these regions and the propagation of this process.

However, it is suggested that deficits in the brain networks underlying this in ASC lead to the disruption of social cognition. Previous work that shows that, in ASC, abnormality exists in the structure and function of the amygdala (Aylward et al., 1999). fMRI research has shown that the amygdala responds atypically to emotional expressions (Ashwin et al., 2007) and differences have been observed in the function of the FFG (Grelotti et al., 2005; Schultz, 2005). This is suggested to lead to atypical social attention and engagement throughout development. For example, research highlighted previously found that young children with ASC do not attend to the social world in a typical fashion (Osterling & Dawson, 1994; Osterling et al., 2002) and young children with ASC are reliably predicted by the lack of interest they show for social patterns compared with non-social patterns (Pierce, Conant, Hazin, Stoner, & Desmond, 2011). As the brain develops through experience, early social interaction allows the brain to refine the areas associated with social reciprocity. However, it is suggested that in ASC, the early lack of social engagement leads to less opportunity to develop the areas of the social brain and causes a circular issue whereby deficits cause a lack of social engagement which leads to atypical development and further social deficits.

This emerging theory is helping researchers to understand the disorder from a biological and social perspective. However, what is less known is how this theory can help us further understand the similarities and differences between those with ASC and people from the typically developing population with high ASC-traits.

By using the social motivation theory of ASC to guide the explorations of how behaviour across the WAS compares to those with ASC, we can gather a better understanding of how a diagnosis of ASC differs from the high end of the typically developing WAS. The above research shows that there are differences in recognition and attention for emotional expressions in those with high vs low ASC-traits in the WAS. These differences are somewhat similar to those seen in ASC, however there are also atypicalities seen in ASC that are not seen in the WAS. Although emotional expressions have been seen to elicit a different response in those at the high end of the WAS, the reasons behind this and how this differs from those with ASC is still unclear. Research has shown that there are behavioural and brain differences in the WAS that are reminiscent of results seen in studies using participants with ASC. However, there is less evidence suggesting how people with ASC represent social emotional information in cognition. Additionally, although we understand that the social attention mechanisms are atypical at the high end of the WAS, there is little research probing this in relation to emotional expressions in order to explore the origin of emotional expression processing differences across the WAS. The current work will test the social motivation theory of ASC using cognitive neuropsychological paradigms to explore emotion expression representation and attention in those at the high end of the WAS and how the behaviour of these individuals relates to the expression of ASC by those with a diagnosis.

# Chapter 2

## Participant Justification and Selection

### **Theoretical framework (2.1)**

The current work uses the social motivation theory of autism in order to understand the mechanisms underlying deficits in emotion processing ability in ASC (Chevallier et al., 2012). The social motivation theory of autism is largely based on atypical development of systems affecting the drive to interact with the social world (see chapter 1). These have been based on knowledge surrounding the underlying brain systems that drive interaction with others and how this differs during the development of those with ASC. However, less is known about how accurately this theory predicts adult outcomes of these earlier difficulties. It is suggested that the lost social experience in childhood results in the underdevelopment of brain areas associated with social attention and cognition. The social motivation theory can be used to make very specific predictions about adult ASC behaviour on cognitive psychology paradigms.

In addition to this, it is important to understand how the WAS differs from diagnosed ASC. One way of understanding this is by assessing high and low ASC-trait individuals from the WAS and seeing how their task behaviour differs from that of people with diagnosed ASC. Using a the social motivation theory to guide this work could help build an understanding of the differences in cognitive mechanisms underlying those with ASC and people in the general population who do not have clinical difficulty in day to day life but do report having ASC-like qualities. Understanding this difference could lead to a better knowledge of where ASC departs from the high end of the WAS and could lead to the introduction of interventions for this developmental condition.

This chapter will justify the use of adult participants. Following this there will be a section on the specifics of participants included for study for each experimental chapter.

### **ASC spectrum (2.2)**

Recently, considerable ground has been made in research assessing ASC-traits in the typically developing population (see chapter 1). Such research often uses self-report

measures of ASC-traits. Self-report measures are typically designed for use with adults, and although measures for children do exist, less research exists using such measures. At the time of conception of the current work, there were three measures of ASC-traits in the typically developing population: the Autism Quotient (AQ; Baron-Cohen et al., 2001), the Social Responsiveness Scale (SRS; Constantino et al., 2004; Constantino et al., 2007; Constantino & Todd, 2000; Constantino & Todd, 2003) and the Broader Autism Phenotype Questionnaire (BAPQ; Hurley, Losh, Parlier, Reznick, & Piven, 2007) (note – newer measures are discussed in chapter 9).

Of these three measures, only one (the AQ) was designed to assess ASC-traits in typically developing adults. The SRS was designed for use with children and requires a parent or teacher close to the child to complete it and the BAPQ was designed to assess traits in unaffected individuals who had a family member with ASC. All three of these tools have their advantages, and results from studies using any of them are useful for the understanding of ASC as a spectrum that reaches through the typically developing population. However, for the current work the AQ has a proven track record of use with adult populations as a purely self-report tool.

The AQ is a 50-item measure that was developed to assess autism-like traits on 5 different subscales that represent areas of difficulty for people with ASC (social skills, communication, attention to detail, attention switching and imagination). Participants are presented with statements such as “I prefer to do things the same way over and over again” and asked to rate their agreement with the statement on a 4-point scale ranging from “definitely disagree” to “definitely agree”. The items are typically scored dichotomously with answers reflecting ASC-like behaviour given 1 point and those that do not reflect an ASC-like behaviour given 0 points. In order to counterbalance the questionnaire, half of the statements presented and scored in reverse, where disagreement with the statement is more suggestive of an ASC-like trait. An example of such a statement would be “I prefer to do things with others rather than on my own”. Completion of the AQ leads to a score between 0 and 50, where higher scores indicate a higher number of ASC-like traits.

The AQ has been shown to have high construct validity over numerous studies. For example, the AQ has been shown to be a tool that is sensitive to the spectrum approach of autism as research supports its ability to detect the presence of a high degree of ASC-traits in relatives of individuals with ASC (Wheelwright, Auyeung, Allison, & Baron-Cohen, 2010;

Woodbury-Smith, Robinson, Wheelwright, & Baron-Cohen, 2005) and has shown that traits are normally distributed throughout the general population (Hurst, Nelson-Gray, Mitchell, & Kwapil, 2007). The AQ was originally reported to have adequate internal consistency for the social subdomain (>.70) and moderate consistency for the other subdomains (>.60) (Baron-Cohen et al., 2001). This was later reinforced by Austin (2005) who found similar reliability scores for each of the subscales.

The current thesis aims to use the social motivation theory to guide assessment of the mechanisms that underlie the emotion expression difficulties seen in ASC and how this relates to the Wider Autism Spectrum. Emotion expression processing in ASC is a well-researched topic. However, less is known about how the difficulties seen in ASC are reflected throughout the general population in individuals with high and low levels of ASC-traits. Research in this area is important as it allows for the assessment of the spectrum approach of autism and how this spectrum relates to emotion expression processing.

The needs of the current study indicate the use of adult participants in the general population due to the use of self-report tools. One reason why adult ASC participants will be chosen for studies assessing emotion expression processing is in order to draw useful comparisons between ASC and the WAS.

Further to this, using a general population sample is preferable in the first instance as it will allow the paradigms being used to be tested without recruiting participants with ASC. Participants with ASC are difficult to recruit and normally travel great distances to take part in the study. Although no participant has more *value* than any other when considering participation, it is certainly worth using a group that is easier to access when assessing the validity of the approach used. For this reason, the studies using those in the general population will serve as a test of the paradigms employed prior to the lengthy process of recruiting clinical participants.

### **ASC-Group (2.3)**

As suggested above, ASC adults need to be used in order to compare results to the general population of ASC-traits. In addition to this, less is known about the emotion processing skills of adults with ASC compared to ASC children. Most research assessing emotion processing in ASC has used children as participants. For example, of the 37 studies assessed in a review by Harms et al. (2010), 25 of the studies included children while only 12 used

adults. Although child participants are necessary when considering a developmental condition such as ASC, as ASC is a lifelong condition, it is also important to study the emotion expression processing differences that occur in adulthood.

The profile of emotion expression processing in children has been shown to vary over time. Although it is important to assess the development of atypical cognition over the course of a disorder in order to assess when it deviates from a typical trajectory, it is also important to understand differences in adult cognition which are relatively stable over time. Despite the large body of work assessing social and emotion expression processing in ASC, less is known about adult cognitive abilities in this area.

Existing research assessing emotion expression processing in adults with ASC has consistently shown a deficit for emotion expression recognition under constraints such as limited response times and subtlety of emotional expression (Law Smith et al., 2010). Additionally, this has been linked with hypoactivity in brain regions associated with emotion expression processing such as the amygdala (Ashwin et al., 2007). However, less is understood regarding the mechanisms that drive the emotion expression deficit in adults with ASC and if this is consistent with predictions made by the social motivation theory.

#### **Control Group for ASC Studies (2.4)**

When assessing ASC ability many of studies employ a control group who also has a developmental condition. For example, control groups with Down's syndrome (Celani et al., 1999; Wishart, Cebula, Willis, & Pitcairn, 2007) or William's syndrome (Lacroix, Guidetti, Roge, & Reilly, 2009) have been used previously to explore emotion expression processing deficits in ASC. This is often employed in order to identify the effects of the condition developmental condition that are specific to ASC and not indicative of general developmental difficulties. However, the current study aims to assess emotion processing ability as it diverges from typical development and relate this to high and low traits of ASC in those with typical development. Therefore, the current study does not seek to employ a developmentally disabled control condition.

Instead, the current study aims to recruit control participants that are matched to the ASC group. As the only aspect that is under inspection is emotion processing ability, the important factors to match are age, gender and IQ. This way, the studies presented in this

work aim to assess the ways that the mechanisms underlying emotion expression processing in ASC deviates from the typical population.

## **Participant Specifics (2.5)**

### *Wider Autism Spectrum Participants (Chapters 3-6) (2.5.1)*

Chapters 3-6 will explore the mechanisms underlying emotion processing differences in individuals with high and low ASC-traits in the general population. These individuals do not hold a diagnosis of ASC, but all vary with regards to the number of ASC-traits they exhibit.

There are at least two common methods of selecting participants for studies assessing the high and low end of the WAS. One method employs a screening phase that assesses the number of ASC-traits an individual possesses prior to inviting them to take part in the study. The advantage of this method is that two (or more) very distinct groups can be sought for study on the basis of being at the high or low end of the WAS. Based on the ASC-trait scores obtained during the screening phase, which is usually conducted via email or during undergraduate classes, only those that fall in the highest and lowest range are invited to participate. This is commonly those who fall in the upper and lower 5-10% of respondents (Poljac et al., 2013). This method is advantageous as it limits the amount of people needed during the testing phase of the study, as only the people required for study are invited to the experimental session. This method is preferable when there is access to a large body of individuals who are willing to undergo screening, or when the research team has access to a database that contains pre-screened scores for ASC-traits. This allows the research team to contact only the participants who meet the study requirements. Although there is scope to screen outside of a university setting, it generally screens from one pool of individuals. This approach is therefore limited to easily accessible populations, such as undergraduate students. This limits the ability to make findings generalizable outside of a university setting. Additionally, as this method generally targets one cohort of individuals, such as psychology undergraduates, there is the possibility that the variance among ASC-trait scores is lower than when assessing a mixture of people from the population due to the target group having related interests and backgrounds.

Where there is not such a pool of readily available participants in place, instead high and low ASC-trait individuals can be obtained by sampling a large number of individuals from the general population and then splitting the sample into high and low ASC-trait groups.

This procedure is more time consuming than the screening method, as this often involves a trade-off between the number of participants needed as dictated by the statistical power requirements of the study and the point at which the split is made. For example, for a study that has a small effect size (and therefore needs a greater number of participants) the split between low and high ASC-trait individuals normally includes most of the sample (i.e. a median split). Under this method the highest scoring member of the low ASC-trait group and the lowest scoring member of the High-ASC-trait group are similar in terms of the WAS profile. However, when the effect size expected from the study is higher, fewer participants are needed in each group. To achieve this a tercile or quartile split can be used in order to create groups such that there is a greater distinction between the two groups. However, this method results in a lot of data that is not subsequently used. The data obtained from individuals in the “middle group” (the group that was not part of the high or low ASC-trait group) is not utilised. This, therefore, requires more time lab based experimental testing time above and beyond the power requirements of the study. This method is the most utilised form of creating groups in the ASC-trait research literature due to the difficulty of obtaining samples large enough to use a screening method.

Grouping the participants into high and low scores is advantages as it allows the study to mimic the studies planned later as two groups will be created. This is similar to having an ASC and Control group in the later studies and will help when trying to compare results across different studies. However, when splitting the data in such a way, there is an issue with the cut point. For example, when using a median split to define groups does lead to issues with the highest member of the “low” group being very similar in their self-report score to the lowest scoring member of the “high” group. Where possible and resources allow, a tercile split will be used to ensure some degree of separation between the two groups. Another way of analysing this data would be to use regression models rather than ANOVA that is presented currently. However, this isn’t entirely appropriate for the current design as the methods used in the presented work utilise repeated measures. When carrying out repeated measures in a regression stacked data can be used, but this is more appropriate for time-series analysis rather than different conditions in experimental trials. This will limit the amount of information we are able to derive arising from interactions. Additionally, using regression in the earlier studies and between groups analysis in the later studies will also make comparisons between the studies difficult to interpret.

In studies in the present work participants underwent the experimental procedure first and were then split into high and low ASC-trait groups for data analysis. This method was



employed due to the limited access to potential participants to employ pre-test screening and the potential to obtain a wider representation of the society and variation in ASC-traits. The specifics of participant selection and group creation will be explained below.

### *Chapter 3 & 4 Participant Inclusion (2.5.2)*

Chapters 3 & 4 used the same pool of participants for both studies. 101 typically developing adults were recruited from the general population. Initially participants completed the AQ and a set of demographic questions. The demographic questions were implemented in order to assess the spread of gender, age, social economic status and ethnicity. In addition to this, participants reported any mental health diagnoses at this stage. This information was used to exclude any data from participants reporting depression or social anxiety as these have been known to impact on emotion expression processing ability. The data from four participants were removed because they reported having a psychiatric diagnosis (3 reporting depression and 1 reporting social anxiety). Further to this, the data from 3 participants were removed because they did not have complete data sets owing to technical reasons. The overall group demographics following these removals consisted of 94 participants (mean age = 28.28; 48 female).

### *Chapter 3 Participant Specifics and Power Analysis (2.5.3)*

The first experimental chapter assessed visual adaptation in order to probe the mechanisms underlying representations of facial emotion expressions in people with high and low ASC-traits. Previous visual adaptation studies in emotion expression research have shown a medium-large experimental effect size (Burton, Benton & Rhodes, 2013; Skinner & Benton, 2012). For reasons made apparent in chapter 3, the current version of this study opted to use a dichotomous response rather than the traditional responses which can allow up to 6 responses (i.e. happy, sad, angry, fear, disgust and surprise). This means that chance level responding is at 50% accuracy which reduces the ease at which a difference can be detected. In addition to this, chapter 3 aimed to assess differences occurring between typically developing individuals in the general population who do not have severe documented difficulty with emotional expressions. The differences between groups are likely to be subtle. Therefore it was predicted that the study would have a small effect size. A power analysis using a predicted small effect size ( $f=.10$ ) and a high correlation between

repeated measures (.65) suggests that 98 participants are needed in order to achieve statistical power at the recommended level of .80. The study, therefore, employed the median split technique to divide the sample into two groups.

Participants with AQ scores in the lower half of the sample formed the low ASC-trait group ( $n = 45$ ; mean age = 28.60;  $AQ < 18$ ; 20 female) and those with AQ scores in the upper half formed the high ASC-trait group ( $n = 49$ ; mean age = 27.92;  $AQ \geq 18$ ; 27 female).

#### *Chapter 4 Participant Specifics and Power Analysis (2.5.4)*

The second experimental chapter assesses differences in attention for facial emotion expressions using the dot-probe task. In addition to the AQ, participants also completed a self-report measure of social anxiety. There is a high co-morbidity of social anxiety in ASC and social anxiety is implicated with performance on the dot-probe task (see chapter 4). In order to address this, the sample completed the Leibowitz Social Anxiety Scale (LSAS; Liebowitz, 1987). The LSAS is a 24 item self-report measure. Participants have to indicate how much they would try to avoid, and how much they would fear, different social situations on a four point scale. The avoidance response scale ranges from 0 “Never” to 3 “Usually” whereas the fear/anxiety response scale ranges from 0 “None” to 3 “Severe”. An example statement that participants need to rate with regards to how much they would fear and want to avoid is: “Working while being observed”.

The dot-probe task has generally been found to elicit a medium effect size (Mogg & Bradley, 1999; Field, 2006). In addition to this the response data collected is reaction time data which, although more variable in nature than the discrete data collected in chapter 3, is less likely to obscure any group differences. This means that there is more chance of detecting an effect in this study. An *a priori* power analysis was conducted using the predicted medium effect size ( $f=.25$ ) and was calculated with an alpha of .05 and a power of .80. This analysis showed that a minimum of 30 participants in total across the two groups were necessary for the study. As the study was conducted at the same time as the study in chapter 4, 101 participants were studied with the same 4 omissions for mental health issues and 2 omissions for incomplete data sets. This left 96 participants upon whom a quartile split was carried out. The quartile split led to a low ASC-trait group ( $n=25$ ; mean age=29.36;  $AQ<14$ ; 11 female) and a high ASC-trait group ( $n=24$ ; mean age=29.36;  $AQ>23$ ; 12 female).

### *Chapter 5 Participant Specifics and Power Analysis (2.5.5)*

Chapter 5 used eye-tracking techniques to build off and interpret the results found in earlier studies. Eye-tracking studies with ASC and ASC-trait research have generally reported a medium-large effect size when looking at data between two distinct groups of people with and without a disorder (Pelphry, 2002). As the current study aimed to split a general population sample, it was assumed that the effect would not be as large. Based on the design used in chapter 5, an *a priori* power analysis for a medium effect size ( $f=.25$ ) calculated with alpha set to .05 and a power of .80 suggested that a minimum of 34 participants would be required in order to obtain statistical power. Initially, it was proposed that his study would utilise a quartile split in order to have separation between the high and low ASC-trait group participants. Oversampling was employed and an initial 80 participants were recruited to participate. This allows for the potential of common issues with hardware and calibration of the eye tracking console to occur and create attrition while still maintaining power with a quartile split procedure.

The 80 participants consisted of UG students, PG students, and staff at the University of Bath. 28 participants would not calibrate successfully due to being unable to pick up on the either the pupil or corneal reflection at each calibration point on the screen. Participants that did not calibrate successfully were not used in this study, leaving 52 participants. A further 13 participants were removed from this study prior to analysis for a variety of reasons: Four participants were removed as the eye tracker did not retain calibration throughout the study and insufficient or inaccurate data was retained for them, determined as any participant with more than 3 trials where their gaze was further than 5 degrees of visual angle away from the fixation point for a whole trial; Four participants were removed after reviewing the video scene data collected by the eye tracking software, as they had unsteady eye tracking gaze patterns which arose from further issues with the corneal reflection; Four participants were removed as they failed to complete the online measure of ASC-traits after several follow up emails; One participant was removed as a technical failure meant that data was not recorded. This left 39 total participants (28 female)

As the number of participants was reduced to 39, to maintain enough participants in each group to meet power analysis requirements a median split was performed leading to a low

ASC-trait group with 19 participants ( $n=19$ ;  $AQ \leq 16$ ; 13 female) and a high ASC-trait group with 20 participants ( $n=20$ ;  $AQ \geq 17$ ; 15 female).

#### *Chapter 6 Participant Specifics and Power Analysis (2.5.6)*

The final study to use a typically developing sample was conducted in order to interpret the results of the previous chapters by assessing whether mild expression representation and considerable time constraints (that were present in previous chapters), could have explained the difference in performance in people with high vs low ASC-traits. Previous studies in ASC show that emotion expression recognition is impaired in ASC and report large effect sizes. The only study to assess this in those with ASC-traits had a much lower effect size due to non-clinical facial emotion processing abilities in typical individuals. However the time constraints used in chapter 6 were predicted to lead to a larger effect size than found in previous studies. It was predicted that the study in chapter 6 would have a small - medium effect size. An *a priori* power analysis for a small - medium effect size ( $f=.15$ ) calculated with alpha set to .05 and a power of .80 suggested that 44 participants would be required in order to obtain statistical power.

105 participants (52 female) with a median age group of 18-25 took part in the current study. Participants consisted of students and staff of the University of Bath, prospective students and their parents attending a University of Bath Open Day, residents of Bath, Wales and Cumbria. They were recruited through advertisements at the University of Bath and personal contacts.

A quartile split was used to divide the sample into high and low autism trait groups based on their AQ score, in order to make comparisons between groups on performance during the experiment. This technique led to a low ASC-trait group ( $n=23$ ; 8 female;  $AQ \leq 13$ ; median age group=18-25) and a high ASC-trait group ( $n=26$ ;  $AQ \geq 23$ ; 10 female; median age group=18-25).

#### *Autism Spectrum Condition Participants (Chapters 7 & 8) (2.5.7)*

Chapters 7 and 8 will explore the mechanisms underlying the emotion processing deficit seen in individuals with clinical ASC using methods previously used in the current work to assess the same aspects in those with ASC. This will allow new insights into the areas of ASC

emotion processing that has not previously been explored while also allowing for comparison to those with high ASC-traits by comparing results across studies. This allows for further assessment of the continuum approach to the autism spectrum that hypothesises that autism is represented across a continuum that stretches into the general population.

When planning research with individuals with a diagnosis of autism, there are varying considerations that need to be accounted for. As autism is a spectrum condition, there are many different abilities represented within its heterogeneous classification. In the UK, the prevalence rates for autism spectrum conditions (ASC) stand at around 1% of the population (Baird et al., 2006; Brugha et al., 2011; Brugha et al., 2009) making participant recruitment particularly challenging. In addition to this, participants can vary by age, gender (although the ratio is assumed to be around 4:1 in favour of males), verbal functioning and intellectual ability. To understand the challenges of studying a heterogeneous disorder that occurs in such a limited population, it is important to first understand what a clinical diagnosis signifies in order to select participants that will help to answer research questions.

ASC is characterised by both social and non-social difficulties. The expression of these difficulties are often diverse, but are encompassed by the criteria set out within the Diagnostic and Statistical Manual of Mental Disorders (DSM-V; APA, 2013; Table 1).

Table 1

*The Diagnostic criteria for Autism Spectrum Disorder (299.00 (F84.0)) from the DSM-V*

<b>A.</b> Persistent deficits in social communication and social interaction across multiple contexts, as manifested by the following, currently or by history	<b>B.</b> Restricted, repetitive patterns of behavior, interests, or activities, as manifested by at least two of the following, currently or by history	
<b>1.</b> Deficits in social-emotional reciprocity, ranging, for example, from abnormal social approach and failure of normal back-and-forth conversation; to reduced sharing of interests, emotions, or affect; to failure to initiate or respond to social interactions.	<b>1.</b> Stereotyped or repetitive motor movements, use of objects, or speech (e.g., simple motor stereotypies, lining up toys or flipping objects, echolalia, idiosyncratic phrases).	To obta in a diag nosis of ASC, indiv idual
<b>2.</b> Deficits in nonverbal communicative behaviors used for social interaction, ranging, for example, from poorly integrated verbal and nonverbal communication; to abnormalities in eye contact and body language or deficits in understanding and use of gestures; to a total lack of facial expressions and nonverbal communication.	<b>2.</b> Insistence on sameness, inflexible adherence to routines, or ritualized patterns or verbal nonverbal behavior (e.g., extreme distress at small changes, difficulties with transitions, rigid thinking patterns, greeting rituals, need to take same route or eat food every day).	s must have sho wn diffic
<b>3.</b> Deficits in developing, maintaining, and understanding relationships, ranging, for example, from difficulties adjusting behavior to suit various social contexts; to difficulties in sharing imaginative play or in making friends; to absence of interest in peers.	<b>3.</b> Highly restricted, fixated interests that are abnormal in intensity or focus (e.g., strong attachment to or preoccupation with unusual objects, excessively circumscribed or perseverative interest).	ultie s in socia l com mun
	<b>4.</b> Hyper- or hypo-reactivity to sensory input or unusual interests in sensory aspects of the environment (e.g., apparent indifference to pain/temperature, adverse response to specific sounds or textures, excessive smelling or touching of objects, visual fascination with lights or movement).	icati on and inter actio n as well

as restricted behavioural interests or patterns of behaviour (routines) to a severity which

impacts upon the functioning of that individual. Social communication can reflect ability that ranges from difficulty understanding the intentions of others to completely limited verbal communication. The severity of the condition is measured on three levels ranging from level 1 “requiring support” to level 3 “requiring substantial support”. These statements help service providers to implement the correct provisions for the individual, but can also be used as a guide when trying to select a participant group with ASC. The current study aimed to limit the heterogeneity seen in ASC by only recruiting individuals with high-functioning autism. This is equivalent to having an IQ in the average range and requiring only mild support in day-to-day life. These individuals are likely to function well in society, but have issues with many of the social interaction and social processing aspects of the diagnosis shown above.

One way of assessing symptom severity is through using clinical interview tools such as the ADI-R (Le Couteur, Haden, Hammal, & McConachie, 2008; C. Lord, Rutter, & Le Couteur, 1994) or the ADOS (Catherine Lord et al., 1989). Standardised assessments such as these require a trained professional to deliver, but allow for an international standard for autism research. These measures allow for independent corroboration of diagnosis to ensure the credibility of the ASC group.

Alternatively, if it is not possible to recruit and test participants on symptom severity, to ensure that participants hold a diagnosis, a copy of their diagnosis certificate should be obtained. In this case, self-report measures of symptoms should also be assessed and can help support the credibility of the sample used in the study. This can be done using an autism phenotype measure, similar to those suggested above. Woodbury-Smith suggest that for screening purposes, an AQ score of 26 or more is indicative of a potential ASC diagnosis.

Financially, it was not within the scope of the current study to acquire training on a standardised clinical assessment to test participant’s symptom severity. Participants were instead requested to bring evidence of their diagnosis and complete a measure of phenotypical autism traits. The current study opted to use the AQ in the sample of individuals with ASC in order to help validate diagnosis alongside obtaining clinician diagnosis certificates.

Both chapter 7 and 8 used the same sample of individuals with ASC and control participants. Participants were recruited via online advertising, emails and personal contacts. To obtain the ASC sample, additional emails were also sent out to supported housing and social support groups.

Participants from chapters 7 and 8 were administered the AQ, the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 2008), the LSAS and were asked to provide age, gender and ethnicity as demographic information. The participants were required to report mental-health issues, but were not excluded on this basis due to the high co-morbidity between ASC and other disorders. The ASC and control participants were matched for age, IQ and gender on a group level.

The overall ASC sample consisted of 23 participants (7 female) with a diagnosis, however one participant did not complete the study leaving a remaining sample size of 22 ASC participants (7 female). For the ASC group, participants had a mean AQ of 32.32 (SD 8.54, range 20-46). The group had a mean age of 28.41 years (SD = 9.20; range 18-48). The ASC group had a full scale IQ in the normal to high range as measured by the WASI with a mean of 111.21 (SD = 9.70; range = 85-127). The ASC group consisted of 19 White Europeans, 1 Chinese and one mixed-race participant.

The control group consisted of 22 participants (7 female) who had a mean AQ of 17.45 (SD = 5.95, range = 5-28), a mean age of 25.95 (SD = 5.74, range 18-45) and a mean IQ of 113.45 (SD = 7.76, range = 99-126). The control group consisted of 17 White Europeans, 3 Chinese and 1 African participant. There were 44 participants in total. All participants were used for both studies.



# Chapter 3 – Study 1

## Using Visual Adaptation to Explore the Mechanisms of Emotion Processing in the Wider Autism Spectrum

### Introduction

This chapter will introduce the literature that relates to visual adaptation. Visual adaptation is a complex topic that needs to be fully understood in order to understand the implications that arise from studies that employ it. This chapter will start with an overview of visual adaptation, before moving onto its use in understanding social perception. Following this, the limited use of visual adaptation to explore social processing deficits in ASC will be evaluated and this will lead into the study aims and hypothesis. The experimental result and discussion will follow the discourse on visual adaptation.

### Visual Adaptation (3.1)

#### *Visual Adaptation (3.1.1)*

Visual adaptation is a process whereby viewing a visual stimulus for an extended period of time results in an aftereffect; a temporary bias in perception for subsequently viewed stimuli. The aftereffect caused by visual adaptation is sometimes referred to as a visual illusion as it distorts perception and creates an effect that only exists within the perceptual system of the beholder. Understanding the mechanisms underlying adaptation is important for grasping why and how adaptation can be used as a tool to understand the human perception system. This is especially true when using adaptation in order to explore social perception. Understanding the mechanisms of visual adaptation also allows insight into how the illusory aftereffects induced by such a process can be interpreted with regards to the function of the visual system.

#### *Understanding Adaptation (3.1.2)*

The first known example of adaptation is the waterfall illusion documented by Robert Addams (1834). The waterfall illusion occurs when a source of downward motion (i.e. a waterfall) is observed for a prolonged period of time followed by looking at a stationary object (such as a rock). This leads to the illusory appearance of upward movement of the

stationary object. This has since been entitled the motion aftereffect and other such perceptual aftereffects have been found in many areas of the human visual system.

In order to perceive the world around us, the human visual system operates through transferring information between neurons at the source (in the retina) and those in higher order processing areas of the brain. Neurons have a particularly narrow firing rate and will only become active when a very strict range of conditions have been met. Firstly, a stimulus needs to be within the range of the neurons receptive field. For example, when referring to retinal cells, this means that photons of light need to come to rest upon the receptive areas of the neuron. With regards to cortical cells, the electrical or chemical signal inputs need to be large enough to cause an action potential. The second requirement is that the cell has to code for the information that it receives. The neurons in the visual cortex are hugely specific regarding the visual information that they will respond to (Gross, Bender, & Rocha-Miranda, 1969; Gross, Schiller, Wells, & Gerstein, 1967; Quiroga, Mukamel, Isham, Malach, & Fried, 2008; Quiroga, Reddy, Kreiman, Koch, & Fried, 2005). Neurons that are exposed to a stimulus they code for will fire in response to that exposure, which in turn sends information signals to the higher level processing areas of the brain. The neurons in higher order areas of the brain that code for the afferent signals arriving from the lower levels of the visual system then fire in response to receiving this information. This process allows the observer to form a perceptual representation of the world; a *representation* of what is truly external to the observer.

The perceiver's created representation is a layer removed from the physical properties of the outside world. The aftereffects created by adaptation are also removed from the physical properties of the outside world. Theories that attempt to explain adaptation aftereffects focus on the internal and cellular level in order to explain the human perceptual experience and how this relates to the misperceptions caused by adaptation aftereffects.

Theories that aim to explain the phenomenon are based on the understanding that neurons are continually firing at what is known as a baseline firing rate (Clifford & Rhodes, 2005; Lodish et al., 2000). This slow rate means that the cell is not specifically responding to anything in the environment. When a stimulus a neuron codes for falls within its receptive field, its firing rate increases in response to this stimulus. Its firing rate will initially reach its maximal firing rate within a short period of time. However, after a prolonged period of exposure, this metabolic and energy consuming process wanes and,

subsequently the neuron will show an inhibition effect. During this period of inhibition the cells firing rate drops below the baseline firing rate.

### *The Neural Fatigue Theory (3.1.3)*

The neural fatigue theory of adaptation proposes that due to the high metabolic consumption endured from the firing process of neurons, the cell enters a period of fatigue. While in the fatigue state the neuron is unable to fire at similar rates until the cell regains chemical balance enough to recover. On a psychophysiological level, once a cell that codes for a stimulus has fatigued, it can no longer play a part in the overall chorus of perceptual representation of that stimulus. In this model, the overall harmony of visual perception is disrupted and the result is a biased visual perception. This is seen clearly in the tilt aftereffect, where participants view a set of tilted lines for a prolonged period of time, before viewing lines that are completely vertical. The percept of the vertical lines is found to be skewed in the opposite inclination to the adaptation stimuli (Gibson & Radner, 1937). Ordinarily, the perception of vertical lines is defined by an equal firing rate of two opponent pools of neurons. One pool codes for leftward tilting lines and the other for rightward tilting lines. When presented with a set of vertical lines, the two pools baseline firing rates are in balance as there is no directionality to the lines' tilt to make either pool of neurons more active than the other. The fatigue account suggests that over exposure to a stimulus would cause the population of neurons that code for that stimulus to exhaust. This population would now fire at levels lower than their baseline firing rate. Thus a situation arises where imbalance in the ability of these two populations to fire equally in response to vertical lines exists. Following exposure to vertical lines following an extended period of viewing tilted lines, what is ordinarily a balancing act between pools of neurons firing at baseline rates can no longer happen because one pool is now exhausted. This would lead to the non-exhausted pool response outweighing the exhausted pool, which would then skew perception in the direction of the non-exhausted pool. Following prolonged exposure to the vertical lines, this perceptual skew rights itself, suggesting that the two opponent pools regain their balance (Clifford & Rhodes, 2005; Gibson & Radner, 1937).

This parsimonious account describes the basic function of the cell and allows for predictions to be made regarding adaptation. For example, recordings from the cat visual cortex has shown that after exposure to contrast gratings (vertical line stimuli), the neuronal firing rate of cells that code for such stimuli show a decline in firing rate and then a further suppression below baseline firing rate following this exposure (Albrecht, Farrar, &

Hamilton, 1984; Hubel & Wiesel, 1959, 1962). However, although the neural fatigue account is plausible, it is unlikely to be a true representation of why neural adaptation effect occurs as some of the predictions it makes are untenable. For example, if adaptation was caused by neuronal fatigue then the fatigue would be expected to dissipate over the course of a rest period. This would predict that there should be no adaptation aftereffect following a rest period where nothing is being viewed. However, studies that have investigated this have shown that an adapted neuron will remain suppressed below baseline firing rate on a neural level and this seems to be the case behaviourally too (Clifford & Rhodes, 2005). In addition to this an aftereffect will still occur after a temporal gap between the adapting stimulus and the test stimulus, regardless of whether there has been any other intermediate viewing of other stimuli. For example, the motion after effect has been explored with regards to this storage effect. Research has shown that when participants view a moving stimuli for period of time and followed by a period of darkness, a motion effect persist following reintroduction to light. The storage effect has been shown to last for minutes and even hours when the ability view another stimuli is removed following adaptation (Wohlgemuth, 1911; Spigel, 1960; Thompson & Wright, 1994; Thompson & Burr, 2009). If visual adaptation was purely a result of fatigue, the adapted cell would not be expected to retain this suppression effect and would be expected to recover over time independent of being exposed to stimuli that excite it. Somewhat more importantly, the neuronal fatigue theory doesn't adequately explain evolutionary reasons behind why this effect should exist. Although reducing the high metabolic cost of cell firing rate by fatiguing cells would be evolutionarily advantageous, the delayed recovery of cells when cell specific stimuli are not present does not fit with this interpretation.

#### *The Functional Account (3.1.4)*

Some early findings in the literature showed that single-cell recordings in the cat cortex before and after adaptation to a contrast grating suggest that there is a shift in the contrast gain of recorded site (Ohzawa et al., 1985). This was interpreted to mean that the contrast gain changes during adaptation as a mechanism to increase the range of responses, and therefore discrimination ability, which can be made. This was followed by studies in human participants who underwent adaptation to contrast gratings before making judgements on further grating that sensitivity for detecting changes in contrast increased for high contrast test stimuli, but decreased in ability to detect low contrast test stimuli (Greenlee & Heitger,

1988). This shows that adaptation can enhance ability in a situation where discrimination is normally poor and further suggests that adaptation is not a by-product of fatigue, but a functional ability.

According to the functional account, adaptation represents a normalisation, or recalibration, of the perceptual system towards the prevalent environmental norms. This process leads to a perceptual skew which may have a functional advantage. There are two possible ways in which aftereffects could be advantageous for survival. The first is as a mechanism that allows for an enhanced perceptual differentiation of two similar stimuli. In this account, adaptation allows for increased perceptual discrimination at the cost of a reduced ability to represent gross changes accurately. It is suggested that perception is a norm-based system, whereby everything that people encounter is judged against perceptual norms or averages. Whether this is something relatively simple, such as colours or shapes, or something more complex as in the case of faces or facial expressions. Our environments are judged in relation to internal perceptual norms which are built up over a certain time scale (seconds, minutes, lifetimes) and are constantly updated by our current surroundings. This system is able to recalibrate itself depending on the current environment and updates itself when presented with new information. Adaptation in this context is the process optimising of the (relatively small) response range of neurons that code for the adapted stimuli through the temporary alteration of a perceptual norm. This allows for the perception of minor deviations from the perceptual norm which would ordinarily be overlooked due to their close similarity.

On the single cell level the functional account of adaptation operates in a similar way to the fatigue account described above. For example, the functional account also suggests that a cell that maximally codes for a given stimulus will appear to fatigue following exposure to that stimulus. However, this account focuses on populations of neurons. On a population level, where surrounding cells are taken into consideration, this effect is less similar to neural fatigue and more akin to a form of gain control. A gain control effect allows for the population of neurons that code for a stimulus to adjust their response range in order to respond to a wider range of stimuli. A low-level example of this is luminance processing. Upon entering a dark room, everything first appears to be the same shade of darkness, which represents the inability to distinguish surfaces of subtly different luminosities from one another. However, after a matter of seconds in the dark room, the perceptual system normalises to the prevailing darkness and is able to pick up on subtle departures from the average luminance. At this point surfaces and shapes become apparent even in

environments with limited light. This ability for coding mechanisms to trend towards the perceptual norm allows for low-light perception to take place through the broadening of neuronal response about the 'low-light' mean (Clifford & Rhodes, 2005).

Secondly, a functional account of adaptation may be advantageous as it could also help to draw attention towards gross deviations from the mean. Through normalising to the current environment, irregularities that deviate from the norm become more salient. Having such a mechanism would allow the perceptual system to readily detect departures from the norm and draw attention towards these departures. This would be beneficial as discrepancies in the environment can be important to attend to in order to increase survival (e.g. threat), therefore attention would be directed towards these discrepancies so that they could be assessed and processed for action. Using the motion aftereffect described in the waterfall illusion (Addams, 1834) shows how adaptation to movement in one direction creates a bizarre distortion for later stationary stimuli. Therefore irregularities in environment become more perceptually salient and draw attention towards them.

#### *Neural Coding of Social Stimuli (3.1.5)*

Before relating visual adaptation to social processing in autism and the wider spectrum, it is important to understand how these mechanisms relate to higher level visual functioning. Adaptation studies, as far as they pertain to social information, have their basis in two key assumptions. The first is one that has been explained thoroughly above; that the physiological make up of a cell dictates that it will fire in response to a stimulus that it codes for (Hubel & Wiesel, 1959, 1962) and that prolonged exposure to that stimulus will result in a reduced firing rate of that cell or population of cells. The second, however, is where the process of adaptation converges with the current topic: there are cells that tuned to respond to social information (albeit perhaps not exclusively) and will react when such social information is within the cell's receptive field (Afraz, Kiani, & Esteky, 2006; Gross, Rocha-Miranda, & Bender, 1972). The remainder of this section will expand on how the brain processes face and social stimuli and how adaptation can be used to explore this before relating this topic to the study of ASC.

Specific neural cells that respond to social stimuli were first discovered by Gross et al. (1972) using single cell recordings. Gross briefly noted a subset of cells in the macaque brain that responded to very specific social stimuli (faces). This was followed up comprehensively by Földiák, Xiao, Keysers, Edwards, and Ian Perrett (2004) using a

technique that allowed the presentation of a vast number of stimuli to be presented to a subject during a recording session. They found that of the stimuli presented (of which there were over a thousand unique images), cells under investigation in the superior temporal sulcus (STS) responded maximally to images containing faces. This was such a robust effect, that the 40 images that elicited the highest rate of responding from these cells all contained at least one face. This result happening by chance with such a dataset has been estimated to sit around the one in a trillion mark (Barraclough & Perrett, 2011). Afraz et al. (2006) later cemented the notion that there are cells specifically responsible for the perception of faces when they recorded neurons in the inferior temporal cortex (IT) of the macaque brain while training the group to distinguish face from non-face stimuli. The researchers not only found that there were specific cells that responded maximally when discriminating images containing faces, but further to this demonstrated that artificial activation of these cells through electrode stimulation biased the judgements of ambiguous stimuli towards classifying them as face stimuli. Research such as this suggests that there are complex cells that code for facial information.

Drawing on the above research regarding the neural basis of adaptation combined with the revelation of face specific cells in the brain, adaptation is a suitable technique for investigating populations of neurons that code for faces. Visual adaptation can allow for the neural representation of faces to be explored in an ethical and non-invasive manner in human subjects.

#### *Variant and Invariant Information in face processing (3.1.6)*

Before going on further to discuss how the representation of faces can be explored using neural adaptation, it is important to understand how the brain codes for the different types of facial information. Facial information can be thought of as one of two constructs, either variant or invariant. All faces are different. This allows us to differentiate between different members of our social groups and our species as a whole. The baseline differences that differentiate members of the species are the invariant properties of the face that do not change dramatically within a short space of time (Bars & Gage, 2010). For example, an individual's facial identity remains relatively stable over the course of a lifetime, and this includes the positioning of facial features, skin tone and gender. On the other hand, variant information is the information that can be displayed on the face, but changes rapidly and normally associated with social signals. An example of this is facial expression.

The distinction between the two types of information presented above is important as there is evidence to suggest that although brain processes for variant and invariant information may overlap to an extent (Ellamil et al., 2008), they are dealt with in different ways by different brain regions. Early research showed that one area of the brain, the fusiform face area, seems to be responsible for the processing of invariant information. This was shown in research by Sergent (1992) who measured brain activity in the fusiform, finding that it responded more readily to face stimuli viewed by participants than to non-face objects. Although more recent research has shown that this area seems to respond to familiarity rather than specifically faces (with faces being the most familiar stimuli we encounter; Gauthier, 2000), there is evidence that this area is evolutionarily hard wired to deal with face stimuli as faces consistently activate different areas of the fusiform than familiar non-face stimuli (Fu, 2012).

However, there is evidence to suggest that differential brain areas, and therefore neural populations are active when variable facial information is viewed. For example, it has been seen that drawing attention to differences in eye gaze direction leads to a lowering in activity in the fusiform and increased activity in the superior temporal sulcus (Hoffman & Haxby, 2000). This is corroborated by research showing that viewing movement in the eyes and mouth results in activation of the temporal cortex rather than the fusiform (Puce, 1998).

Evidence that emotion expressions are processed by separate neural populations than those that process invariant facial information comes from research that shows higher activation in the superior temporal sulcus than the fusiform when a participant is asked to judge an emotional expression in comparison to a task that requires them to detect the presence of a face (Streit et al., 1999). Further, this study showed that when participants engaged with an emotional expression, activity correlated with later activity in the amygdala. This suggests an important link for disorders that implicate this brain region.

Although such research suggests that different areas of the brain process emotional expression and other invariant and socially meaningful information, this does not mean that the two do not work together. It is likely that both systems work in harmony during face processing, but that specific tasks have specific neural resources available to them. This was shown by Ellamil, Susskind and Anderson (2011) who used visual adaptation in order to see to what extent the successful representation of emotion expression relied on the non-variant feature of identity. They found that adaptation effects were stronger when



the identity of the adapting image was kept constant, and although changing the identity between adaptation and test didn't eliminate the effect, it did decrease it.

Overall, the research suggests that variant and non-variant facial information is processed by distinct neural populations that work together in order to build an informative representation of the social world.

#### *Adaptation to social information (3.1.7)*

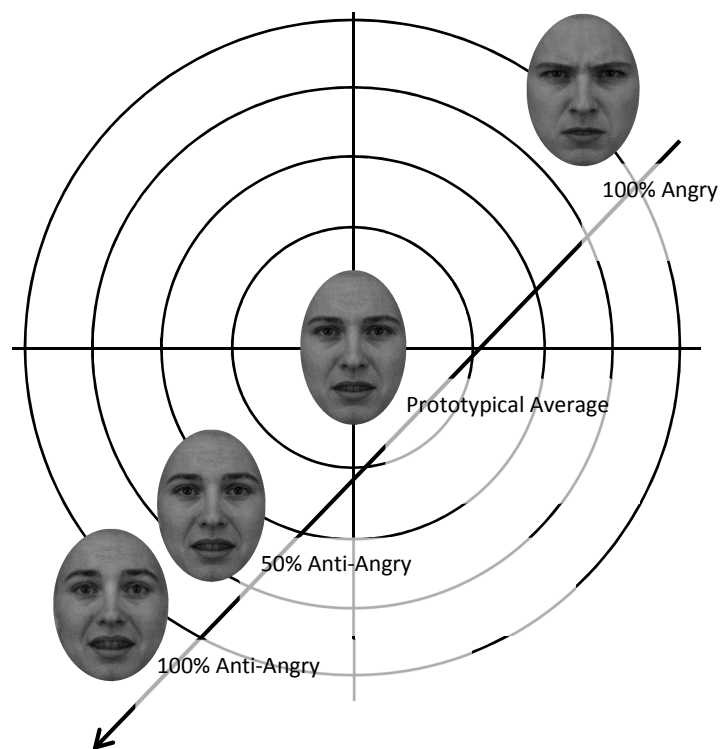
The first adaptation study to explore the neural representation of faces used expanded or contracted face stimuli prior to a probe face that had not been altered. Perceptions of the probe face varied depending on the nature of the adaptation stimuli. After exposure to an expanded face, the probe face appeared contracted, and adaptation to a contracted face resulted in an expanded aftereffect (Webster & MacLin, 1999). Further to this, the researchers showed that the aftereffect was most prominent following adaptation to stimuli with the greatest level of distortion. This was the first study to show that higher order visual social information was also subject to adaptation and therefore could be explored using this tool. However, the aftereffects evoked in this study were not socially meaningful as the adapted perception was merely an expanded or contracted face. Therefore, the adaptation aftereffect discovered in this study could be an artefact of low level visual adaptation rather than adaptation of neural populations that represent social information.

This has since been explored through studying the effects that adaptation had on an individual's subsequent judgements of a facial identity. There have been several models and theories that try to account for facial identity adaptation. Research and models are based on the principle of a 'face space'. The workings of the face space, however, differ with the models that are best trying to explain its function.

The exemplar-based face space proposed by Valentine (1991) assumed that the similarity of two representations will be based on the distance between these two representations. This suggests that two representations that are close in face space will be more similar in appearance than two that are further apart. It is critical to note that this is a relatively stable assumption across different face space models. The second assumption is that, owing to the biological nature of facial features, the differences in faces from a homogenous group (i.e. race) will follow a normal distribution. The consequence of this assumption is that there will be a high density of exemplar faces close to typical or 'average' identities, and a sparser range at further distances from the average. This model

suggests that when exemplars are densely packed, categorising faces is relatively easy, but learning new faces or recognising a face becomes harder. This model is able to account for a lot of the observed differences in facial structures. It assumes that a face will be recognised based on the similarity to the most similar exemplar and the next most similar exemplar (taking into account encoding errors, Valentine 1991; Valentine & Endo, 1992)

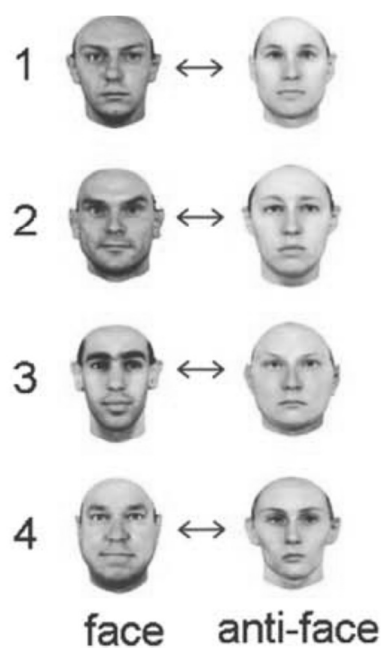
Another model is the Prototype referenced face space, which suggests that the vast array of facial information can be represented as deviations from a prototypical face as a central average (see Fig 3.1 for an example involving emotional expressions).



*Figure 3.1.* A representation of 'Face-space' which shows how expressions and other facial information can be represented as deviations from an average, prototypical norm

This is referred to as a prototype-referenced system. For example, altering an identity along a trajectory in face-space that intersects the prototypical average can make that identity more subtle or a caricature of itself. This process is thought to be synonymous with the way the brain represents facial information on a neural level, as the face-space is a system that is capable of coding for a vast array of differences and diversity in facial information. Anecdotal evidence for this arises from the phenomenon that it is easy to

identify a caricature of an individual, which is an extreme position along an identity trajectory. Computationally, this process can allow for the creation of a variety of differences in facial identity, and even the creation of conceptually opposite identities (called anti-faces) by altering the identity along a backwards trajectory through the prototypical average face to a position on the opposite side of the face-space. Anti-face identities will be structurally opposite to their original identity counterparts. For example, if the original face had a small nose and wide face, the anti-identity would have a large nose and thin face (fig 3.2).



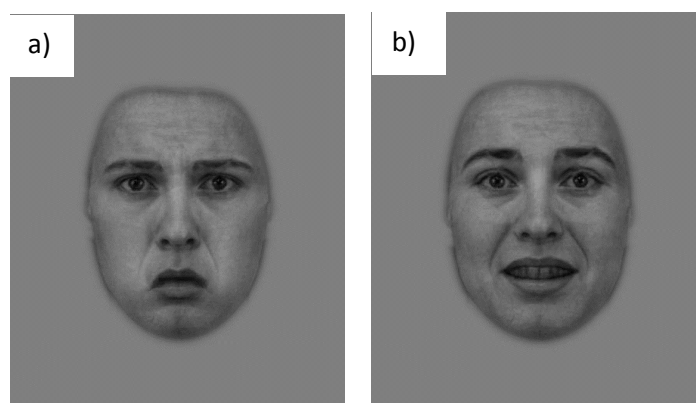
*Figure 3.2.* Stimuli used in Leopold et al. (2001) which depict faces and their computationally derived anti-face identity partners (from Tsao & Freiwald, 2006).

Leopold, O'Toole, Vetter, and Blanz (2001) used computer generated facial identities and counterpart anti-identities in order to explore the adaptation aftereffect with regards to the socially meaningful construct of facial identity. The authors were able to show that following adaptation to an anti-face identity, perceptions of prototypical average faces, which have no unique or identifiable identity, were biased towards the anti-face's corresponding typical-identity. Moreover, after adaptation to an anti-identity, participants were more likely to make correct judgements of mild representations of the corresponding typical-identity than they were prior to adaptation. These effects were found even after controlling for low level adaptation effects, such as shape adaptation and retinal adaptation, and have been consistently shown in subsequent research (Loffler, Yourganov, Wilkinson, & Wilson, 2005; Nishimura, Maurer, Jeffery, Pellicano, & Rhodes, 2008; Rhodes & Jeffery, 2006). This research suggests that face specific neural populations can be probed through visual adaptation and that face adaptation aftereffects are unlikely to be a product of low-level adaptation occurring in the retina or other subcortical processing areas.

While facial identity is a stable characteristic, some types of information obtained from the face change over time. One such type of variant facial information are emotional expressions. Research has shown that when individuals undergo adaptation to a specific emotional expression stimulus, their judgements subsequent ambiguous expression show a perceptual biases. For example, Fox and Barton (2007) probed this using emotional expression morphs. Morphs are created by blending two stimuli at different strength levels of each stimulus. For example, a morph made from Fear/Anger expressions would look ambiguous at an equal 50:50 morph ratio, but the expression would become clearer as these ratio levels become more disparate. Participants were adapted to an explicit expression stimulus before being probed with a morph of two blended emotions. Following adaptation, participant responses were generally biased away from the adaptation stimuli. For example, participants who adapted to a fear expression perceived a Fear/Anger morph as having an angry expression. This suggests that there are neural populations that code specifically for emotional expressions, which are variant and transient facial information. This is especially reinforced as separate from structural information (i.e. identity, race etc.) as the effect for emotional expression adaptation was found even when the adaptation stimuli differed from the probe stimuli on the basis of identity and gender. This makes it unlikely the adaptation is due to a low level perceptual effect, as the visual information presented on the adaptation and probe faces differed significantly from one another. This effect shows that variant facial information can be probed by adaptation. Specifically, the

results could represent the functional aspect of adaptation with regards to social information, as this study caused the perceptual system to normalise to the present environment (i.e. fear) in order to detect important departures from this environment (i.e. the presence of another emotion; aggression). However, it is uncertain whether the emotional expression information was represented in the same prototype-reference model as non-variant social information such as identity. If this was the case, the strength of the afterimage will rely on the perceptual strength of the adaptation stimuli. A more expressive fearful adaptation expression should lead to the fear/anger morph looking more obviously angry.

Skinner and Benton (2010) demonstrated that variant facial expression information is, in fact, represented in a prototype-reference model by employing a similar technique to that described in Leopold et al. (2001), but using anti-expressions. The key difference between using anti-expressions as opposed to typical expressions is that they are created to be the polar opposite to a typical expression (the anti-expression) and are often gross deformations that do not typically exist in the real world. Note that this is not to say that they cannot exist, but they are not expressions that, themselves, are associated with an underlying feeling, emotion or mental state (fig 3.3).



*Figure 3.3.* Examples of anti-expressions of a) anti-happy and b) anti angry

In order to show that expression information is represented in the same prototype references manner as other structural facial information, Skinner and Benton (2010) adapted participants to anti-face representations of emotional expressions that varied in

adaptor strength. Adaptor strength is the term used to describe the distance between the prototypical average face to an anti-expression in relation to the distance between the prototypical average and the original typical expression (see fig 3.2 above). Stimuli with larger adaptor strength are more pronounced and expressive, whereas stimuli with a low adaptor strength are normally subtle expressions. If expressions are coded in a similar fashion to structural social information such as identity, it would be expected that adapting to an anti-expression with higher adaptor strength will result in a large aftereffect which will resemble the typical-expression it relates to (Tsao & Freiwald, 2006). The authors found support for this hypothesis as participants were more likely to report that a briefly displayed prototypical average face expresses the counterpart emotion of the adaptation stimulus rather than any of the other 5 basic emotions. Further, this effect was found to be stronger for 100% strength anti-expression adaptor stimuli than for 50% strength stimuli. This shows that facial emotional expression information is likely processed in a prototype referenced model in a similar way to non-variant information such as identity.

As the ability to probe the representation of facial information using adaptation has been repeatedly shown using a variety of methods, this tool is potentially one that can be used to probe the deficits with social information present in psychological and developmental conditions.

#### *Adaptation to social information in ASC (3.1.8)*

People with ASC have been shown to perform poorly on tasks involving adaptation to social stimuli such as identity (Pellicano, Jeffery, Burr, & Rhodes, 2007) and gaze direction (Pellicano, Rhodes, & Calder, 2013). Pellicano et al., (2007) trained children with ASC to recognise sets of identities. Participants then took part in a series of trials where they were adapted to the corresponding anti-identities. Following adaptation to an anti-identities, subjects would be expected to label subsequent aftereffects as the corresponding identity (i.e. following adaptation to “anti-Jim”, aftereffects should resemble “Jim”). However, although children with ASC could discriminate between two typical identities, they were not able to correctly label the identity aftereffect arising from adaptation. In addition to this, Pellicano et al., (2013) tested children with ASC on a gaze discrimination task pre- and post-adaptation. In this task children had to judge whether a pair of eyes were looking (subtly) to the left or the right. Although there was variation in the ASC participants, it was found that pre-adaptation, ASC children could complete this discrimination task. However,

following adaptation to gaze, although both the control and ASC group showed reduced gaze sensitivity, the ASC group's performance was similar to their baseline performance, suggesting that they were not able to show typical gaze aftereffects. This suggests a deficit in the adaptation mechanisms in this group.

During tasks such as those presented above, adaptation should increase the ability to distinguish subsequently presented ambiguous stimuli or give the appearance of some socially meaningful information in a neutral stimulus. Drawing on the evidence and explanation presented throughout this chapter, this would suggest that people with ASC may have problems representing social information in an adaptive manner and therefore developing strong aftereffects following adaptation. This might suggest an issue with representing social information in the brain. This could therefore apply to other forms of social information such as facial emotion recognition. Further to this, people with ASC may not represent social information in a typical fashion. If this is the case, they may instead use compensatory rule-based strategies (Rutherford & McIntosh, 2007) which by their nature are slower, less flexible and more prone to errors. The inability to represent social information in a typical manner may reflect the brain basis of the social issues that present themselves in ASC and using a visual adaptation paradigm may allow the exploration of this facial emotion processing deficits seen in ASC.

Rutherford, Troubridge, and Walsh (2012) used adaptation to explore emotion expression processing in ASC by presenting typical emotion expressions as adaptation stimuli before presenting a neutral face as the target probe. Following adaptation, it is expected in this case that the aftereffect will have the opposite valence to the adapting image. The results showed that people with ASC were less likely than control participants to perceive an aftereffect when presented with the neutral expression probe. Control participants were likely to report that the neutral expression probe looked positive when the adaptation expression was negative and vice-versa whereas there was no such pattern of responses in the ASC group who reported that the probe expression looked negative following adaptation to negative expressions. However, there are some potential methodological limitations with this study. Firstly, individuals in the study were only adapted to typical representations of expressions, prior to being exposed to a neutral expression probe stimuli. Since the perceptual system is thought to code for social information based on a prototype referenced system, the aftereffects produced subsequent to adaptation should be shifted in a diametrically opposite trajectory from the adapting stimuli. When adapting participants to typical expressions and then testing them with neutral faces, the resulting

aftereffects based in this system may have an opposite valence to the adaptation stimuli but do not have a typically characterised expression. Consequently, when Rutherford et al., asked participants to label the expression evoked by the aftereffect, it is meaningless to ask them to use emotional labels and words. An interesting way to explore this would be to have participants make valence judgements of the aftereffects rather than confounding this with emotional expression labels which are not reflective of the aftereffect. In addition to this, people with ASC have been shown to have difficulty with verbal labelling tasks, and a valence recognition task may help avoid such issues with ASC participants. In order to probe emotion expression representation in ASC effectively, studies need to employ stimuli which will effectively probe these mechanisms through the induction of meaningful aftereffects. One way of inducing such meaningful aftereffects is through the use of anti-expression stimuli that are specifically designed to probe such phenomenon (Skinner & Benton, 2010).

As suggested previously, the ability to adapt to emotional expressions could be a functional ability, which leads to enhanced discrimination or greater detection of irregularities. These consequences would be advantageous for social communicative interaction. If an individual does not possess the ability to adapt in such a way, opting instead to use compensatory strategies such as rule-based processing, such individuals would not benefit from the functional advantages of adaption. By exploring the ability to adapt to emotional expressions across the autism spectrum, it may be possible to understand real-world facial emotion processing difficulties that arise through not being able to quickly adapt to a social situation.

The exploration of facial emotion expression adaptation can be guided by the social motivational theory of ASC. The social motivation theory suggests that areas used for social processing do not develop in line with typical development due to the limited drive to interact with the social world. The lack of experience with the social world could hinder the development of representational systems that underlie emotion expression processing. Therefore using a visual adaptation paradigm could test the social motivation theory of ASC.

In addition, it is important to further understand the relationship between ASC-traits and emotion expression processing mechanisms in the WAS. This link has recently been shown to exist for biological motion, which is one aspect of social information (van Boxtel & Lu, 2013). People with high ASC-like traits are less able to adapt to biological motion in order



to make subsequent judgements of motion. This effect is only seen when local processing was prevented by presenting the adaptation and test stimuli at different points on the screen. This suggests that social adaptation mechanisms may be impaired at the high end of the WAS, especially if this is defined by people high in systemising, who may prefer to use a local processing style. However, this study looked at the biological movements of 'walking' versus 'running', which conveys social meaning but does not have the ability to convey the same wealth of social information as faces and emotional expressions. There is currently no work that assesses the adaptive neural representation of social information with regards to emotional expressions across the WAS. This research is important in order to explore the differences that exist across the WAS in the ability to adaptively represent emotion expression information and how this relates to the social motivation theory of ASC.

The current study used a visual adaptation paradigm with facial emotion expressions to investigate the mechanisms underlying emotion processing in people with high ASC-traits.

#### *Aims and hypotheses (3.1.9)*

The aims of study 1 were to: (1) assess for differences in ability to adapt to positive and negative emotion expressions in those with high and low ASC-traits; (2) to see if this differs for positive and negative emotional expression aftereffects (3) to explore whether there is evidence for an adaptive, prototype referenced system for encoding emotion expressions in people with high autism traits and (4) to assess non-social adaptation ability in these two groups.

In accordance with the social motivation theory, it was hypothesised that people with high ASC-traits will (1) show reduced aftereffect perceptions overall compared to the low ASC-trait group and that (2) the high ASC-trait group will have greater difficulty on visual adaptation trials that probe representations of negative valence emotional expressions.

It is also hypothesised that (3) the high-ASC-trait group will not show an increased performance for 100% strength adaptors over 50% strength adaptors due to an under-developed representational system that would be expected under the social motivational theory. Finally, it was hypothesised that (4) there would be no group differences in non-social adaptation as this should be spared from a social motivational perspective.

## Method (3.2)

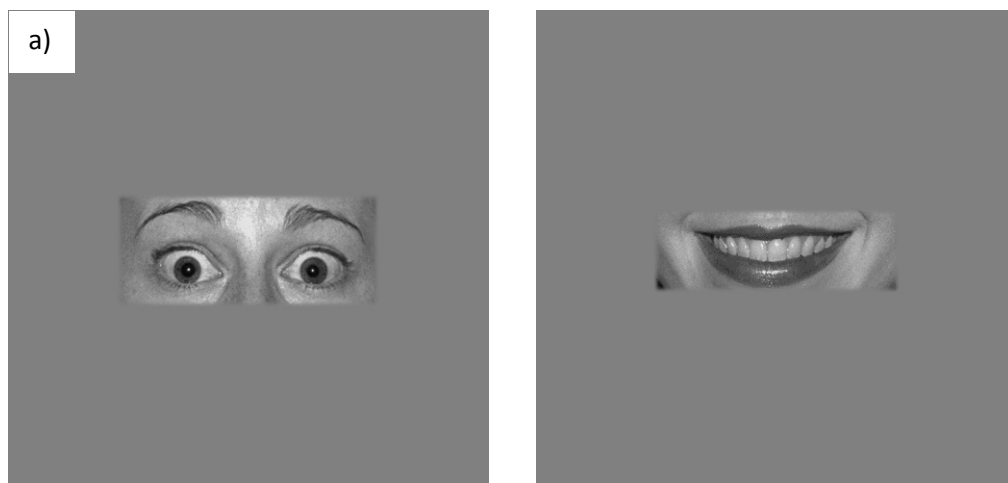
### Participants (3.2.1)

One-hundred and one healthy adults (52 female; mean age = 27.99 years; SD = 8.04) were recruited from the University of Bath and local community through poster advertising and via the online university notice board. The sample consisted of undergrad and postgrad students, staff at the University, and people from the local community. All participants completed the AQ (Baron-Cohen et al., 2001) as a measure of autism traits. The data from four participants were removed because they reported having a psychiatric diagnosis (3 reporting depression and 1 reporting social anxiety), and the data from three further participants were removed because they did not have complete data sets for technical reasons. In total, the data from the remaining 94 participants (48 female, mean age = 28.28 years, SD = 8.18) was included in the analyses. The AQ scores of participants were used to divide the sample into autism trait groups by means of a median split. Participants with AQ scores in the lower half of the sample formed the Low ASC-trait group ( $n = 45$ ;  $AQ < 18$ ) and those with AQ scores in the upper half formed the High ASC-trait group ( $n = 49$ ;  $AQ \geq 18$ ).

### Stimuli (3.2.2)

#### *Emotion Recognition and Valence recognition baseline tasks (3.2.2.1)*

An emotion expression perception baseline task was included in the current study. Stimuli for this baseline task were taken from the NimStim set of emotional faces (Tottenham et al., 2009) and the KDEF (Lundqvist, Flykt, & Ohman, 1998). The NimStim images were cropped into a uniform rectangle to show only the eye or mouth region of the face (fig 3.4a). The KDEF images were left as complete, full face images. All images were converted to greyscale and matched for luminance (fig 3.4b).

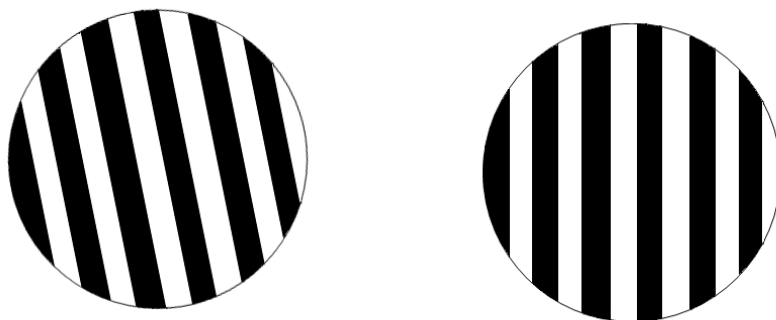




*Figure 3.4.* Examples of a) Face part expression stimuli and b) full face valence recognition stimuli

#### *Tilt Adaptation Baseline Task (3.2.2.2)*

The current study used a variety of tilted lines to assess baseline non-social adaptation ability. Seven arrays of lines were created in GIMP 2.0. The test stimuli were a set of vertical lines with a rotation of 0°. The adaptation stimuli consisted of sets of tilted lines which were either clockwise or anticlockwise in orientation from vertical by 5°, 15° or 25° (fig 3.5).



*Figure 3.5.* Examples of a tilt adaptation stimulus and the test stimulus

### Emotion Expression Adaptation (3.2.2.3)

The current study utilised morphed expression stimuli taken with permission from Skinner and Benton (2010). These were originally created from images taken from the Karolinska Directed Emotional Faces database (Lundqvist et al., 1998). The KDEF is an international image database that has been validated as having good representations of the emotions that the stimuli display (Goeleven, De Raedt, Leyman, & Verschuere, 2008). The morph stimuli consisted of seven of the morphed faces displaying typical- and anti-expression facial representations, as well as an expressionless prototypical average face. For more information on the creation of the stimuli see Skinner and Benton (2010).

The current study utilised the typical- and anti-happy facial expression stimuli, typical- and anti-angry facial expression stimuli and the prototypical average face from Skinner & Benton (2010). The anti-expression adaptors were for both 50% and 100% adaptor strength were used. Therefore the current study used 6 adaptation stimuli in total: 4 anti-expression adapting stimuli (50% and 100% anti-happy and 50% and 100% anti-angry) and 2 typical-expression representations (typical-happy and typical-angry).

### Procedure (3.2.3)

All aspects of this study were presented to participants using E-Prime version 2.0 (Psychology Software Tools, Pittsburgh, PA) on an Intel Core 2 Duo CPU E7500 desktop PC system running Windows 7 displayed on a 18 inch LCD monitor with a resolution of 1280x1024 pixels. Testing was completed in a dimly lit room and participants sat approximately 57cm away from the centre of the computer screen.

#### *Emotion recognition task (3.2.3.1)*

Participants completed a short facial emotion recognition task. Participants were required to fixate on a crosshair fixation point for 500 ms until one of the emotion expression stimuli were shown on screen. Participants then had to identify the emotions displayed in the face-part and were instructed to use the keyboard number pad to make their responses. 6 on-screen response options relating to a number key on the keyboard. Both the image and the response options were shown on screen for 10000 ms or until the participant registered a response. The screen was then cleared and the next trial began. This task presented

participants with 72 trials displaying face-parts (Eyes or Mouth) depicting one of the six basic emotions. There were 6 eye and 6 mouth stimuli for each of the six basic emotional expressions.

#### *Valence recognition baseline task (3.2.3.2)*

60 of the participants also completed a valence recognition baseline task, where they classified facial expressions as having positive or negative valence. This task presented participants with 45 different images of actors displaying emotional expressions taken from the KDEF. The participants judged 15 happy, 15 angry and 15 neutral expressions, presented within one block in a randomised order. Participants had to respond with the up or down arrow keys to indicate whether they thought the face had positive or negative valence respectively. Each image was displayed on the screen for 10000 ms or until the participant made a response before the screen was blanked and the fixation crosshair was presented for 500ms preceding the next trial.

#### *Tilt Adaptation Baseline Task (3.2.3.3)*

Participants completed a non-social baseline test of adaptation. Following a fixation cross for 500 ms, participants were presented with 2 arrays of lines on each trial: an adaptation array and a test array. The adaptation arrays consisted of lines tilted either to the left or to the right for a period of 5000 ms. The incline of these lines varied from trial to trial and were either 5°, 15° or 25° on the clockwise trials or 355°, 345° or 335° on anticlockwise trials. The adaptation stimuli was presented at the centre of the screen. Following adaptation, the array was removed and replaced with a probe array of vertical (0°) lines for 300 ms before the word RESPOND appeared on the screen for 10000 ms. Participants were instructed to observe the adaptation array and then report whether the second probe array appeared to be tilted to the left or to the right. A standard keyboard was used for responses. Participants used the 'z' and 'm' keys to indicate whether they thought the probe looked tilted left or right respectively. These keys were labelled with stickers to indicate which one should be used for each response.

If participants did not respond within the allotted time, a null response was recorded. Typically, after adapting to tilted lines, subsequent vertical lines with a mild degree of tilt (5°) appear most tilted in the opposite direction to the adapting stimulus, with greater deviations from vertical leading to an attenuated effect (Gibson & Radner, 1937).

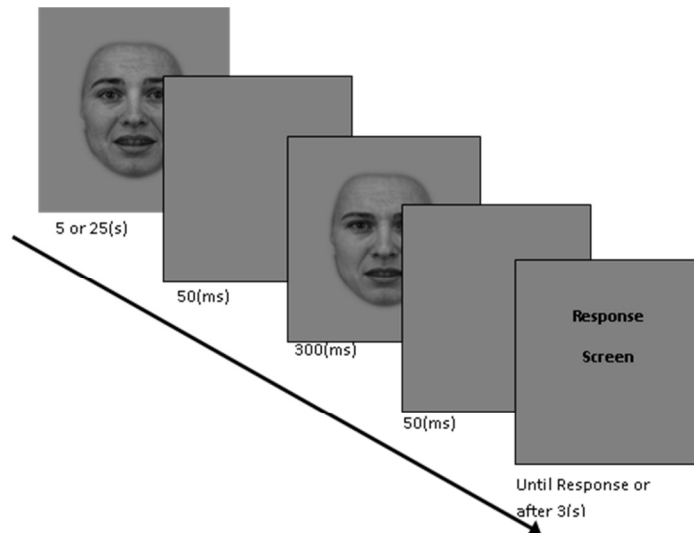
Responses were scored as correct if the participant responded that they perceived the line to be tilted in the opposite direction to the adapting stimulus. There were 60 trials in total with a short break after every 12 trials.

#### *Emotion Expression Adaptation (3.2.3.4)*

Participants also completed an emotion expression adaptation task. This task consisted of 24 blocks of trials, with 6 trials in each block, making a total of 144 trials for the task. One trial within every block was a distractor trial, which used the same adaptation stimuli but used one of two different expressions as the target face (surprise or disgust). This was included to limit the possibility of participants realising that the target face did not change. The distractor trials were not of theoretical importance so were not included in the analysis. In total, participants made 20 judgements of the perceptual aftereffects for each of the two 50% and 100% strength anti-expression conditions, and 20 judgements for the each of the two typical-expression conditions for a total of 120 trials.

For the first trial of each block the adaptation stimuli was presented for 25000 ms, while for subsequent trials within the block the adaptation stimuli was presented for 5000 ms as a 'top-up'. This structure allowed initial induction of adaptation and subsequent adaptation top-ups throughout the block to the continuation of adaptation effects throughout. The adaptation stimuli were the same within each block.

A single trial involved the participant fixating on a point in the centre of the screen while one of the 6 expressional adaptation stimuli was randomly presented and moved around the fixation point in a circular trajectory once every 5 s with a radial movement path of  $1^{\circ}$  of visual angle. This was employed to prevent low level retinal adaptation aftereffects. Following exposure to the adaptation stimuli the screen was blanked for 50 ms before the probe face (the prototypical average face) was displayed for 300 ms. After the probe face was removed from the screen, a blank screen was shown for a further 50 ms before the word "RESPOND" was presented on screen (see Fig 3.6).



*Figure 3.6. An example trial from the emotion adaptation task.*

Participants then had up to 3000 ms to respond whether the probe image appeared to have a positive or negative valence. A standard keyboard was used for responses. Participants used the 'z' and 'm' keys to indicate whether they thought the probe face looked positive or negative in valence respectively. These keys were labelled with stickers to indicate which one should be used for each response. If the participant did not respond in time, the next trial began automatically. After every 6 blocks participants took a short break.

## Results (3.3)

### *Demographics (3.3.1)*

An independent samples t-test showed that the high and low AQ groups did not differ on age ( $M = 28.33$ ,  $t(47) = 0.88$ ,  $p > .05$ ). A chi square test revealed no significant differences between groups in terms of gender ratio ( $\chi^2(1, N = 94) = 0.18$ ,  $p > .05$ ).

### *Emotion feature recognition tasks (3.3.2)*

A repeated measures ANOVA was conducted on the accuracy data for the emotional expression features task with Emotion (Happy vs Angry vs Sad vs Surprise vs Fear vs Disgust) and Feature (eyes vs mouth) as the within group factors and Group (low AQ vs high AQ) as the between-subjects factor. There was a main effect of Emotion ( $F(5,440) = 198.28$ ,  $p < .01$ ) and Feature ( $F(1,88) = 66.61$ ,  $p < .01$ ). Results showed a significant interaction between Emotion and Feature ( $F(5,440) = 56.22$ ,  $p < .01$ ). Post-hoc *t*-tests showed greater accuracy for the mouth of the face versus the eyes for Disgust, Happy and Sadness ( $p$ 's  $< .05$  after Bonferonni correction). For Surprise and Anger, the eye region was identified correctly more often than the mouth region ( $p$ 's  $< .05$  after correction). For Fear, the eye region was more accurately identified, but significance did not remain following Bonferonni correction ( $p = .49$ ). There were, however, no main effects or interactions involving Group (all  $p$ 's  $> .05$ ) (fig 3.7).



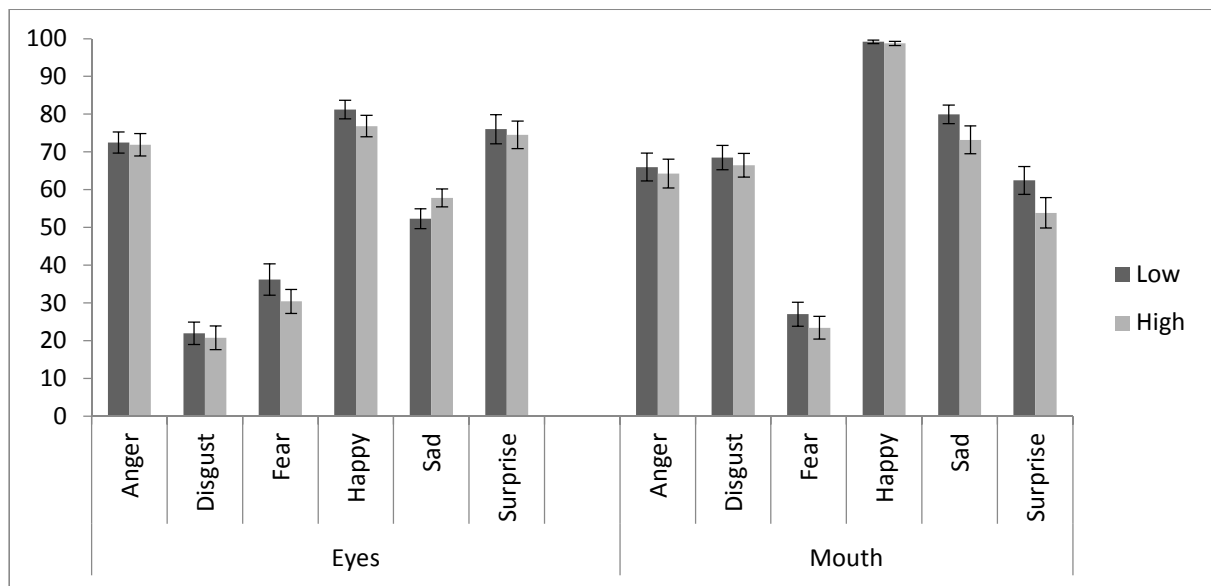


Figure 3.7. Bar graph showing the percentage of correctly identified emotional features

#### Emotion valence task (3.3.3)

A repeated measures ANOVA was done on the accuracy data for the emotion valence recognition task, with Valence (Positive vs Negative) as the within groups variable and Group (Low AQ vs High AQ) as the between group variable. The results did not reveal any significant main effects or interactions (all  $p$ 's > .05) (fig. 3.8).

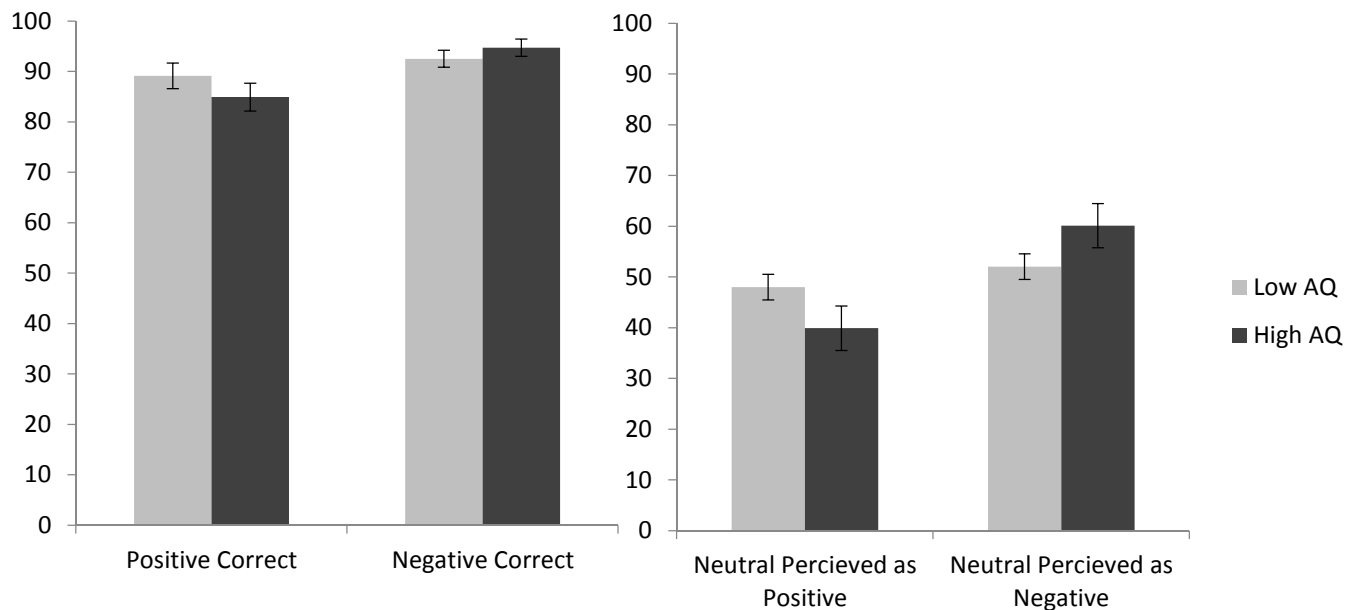
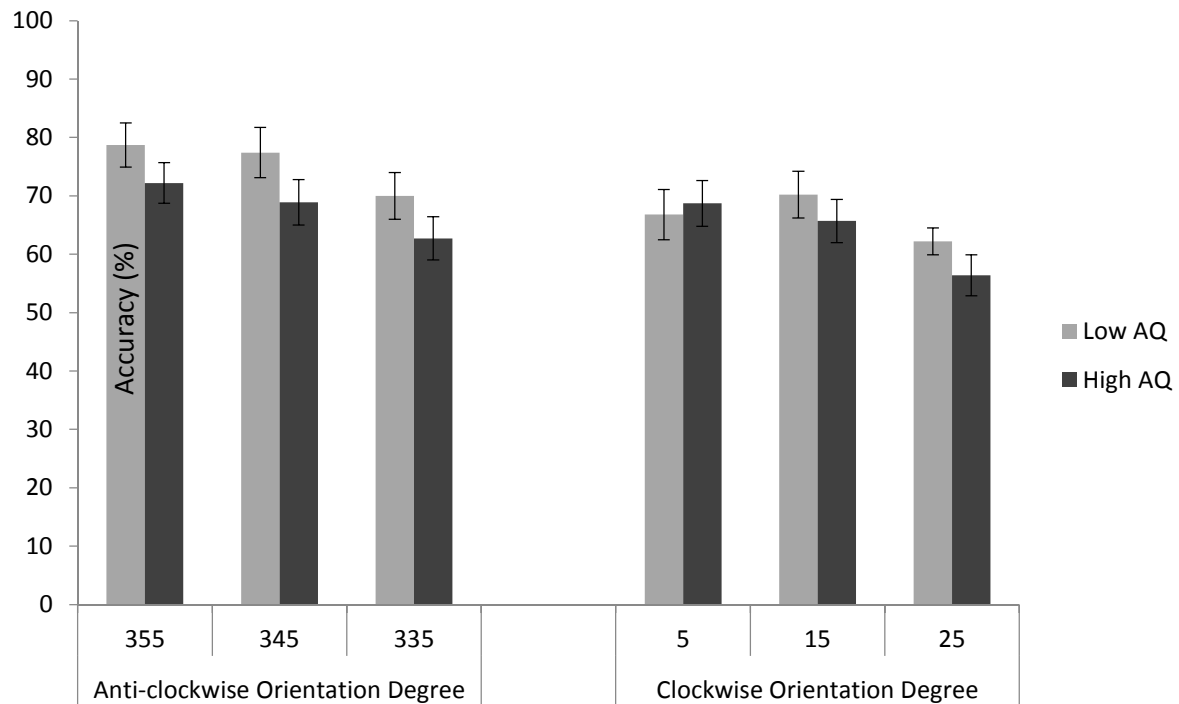


Figure 3.8. Bar graphs showing (a) the mean percentage of positive and negative expressions correctly categorised by low and high AQ group members and (b) the mean percentage of neutral faces classified as positive or negative by high and low AQ group members.

An additional analysis assessed participant response to Neutral expressions. For this analysis a between subjects t-test was conducted for response data for neutral faces finding no difference between how people with High and Low traits of ASC classify the valence of neutral expressions ( $p > .05$ ) (fig 3.8).

#### *Tilt adaptation baseline task (3.3.4)*

A repeated measures ANOVA was conducted on accuracy data for the tilt aftereffect baseline task with a within subjects factor of Direction (Left vs Right) and of Tilt Degree ( $5^\circ$  vs  $15^\circ$  vs  $25^\circ$ ). As expected, results showed a main effect of Tilt, suggesting the entire sample showed a typical tilt aftereffect which varied as a function of initial adaptation display angle ( $F(2,162) = 23.30$ ,  $p < .05$ ) with a greater angle leading to a reduced adaptation effect (fig 3.9).



*Figure 3.9.* Bar Graphs showing accuracy scores the extent of baseline adaptation for High and Low AQ groups for each orientation of adaptation stimuli.

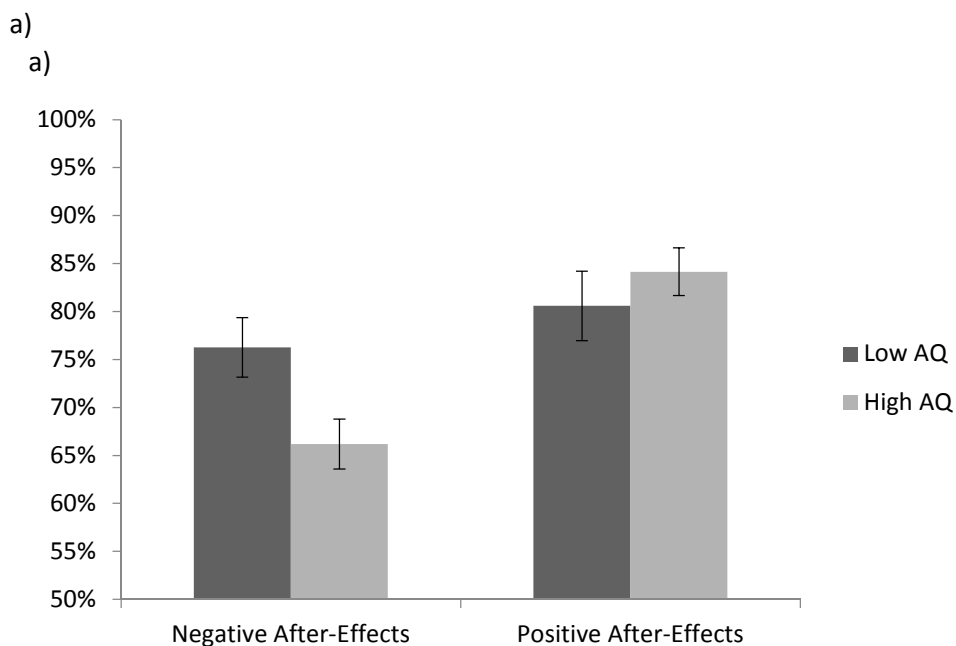
There was a trend towards significance for greater accuracy for aftereffects that appeared to tilt right ( $F(1,81) = 3.70, p=.059$ ). There were no Group differences for the High and Low AQ groups with respect to how they viewed the probe array of vertical lines following adaptation to tilted lines ( $F(1,81) = 1.99, p >.05$ ).

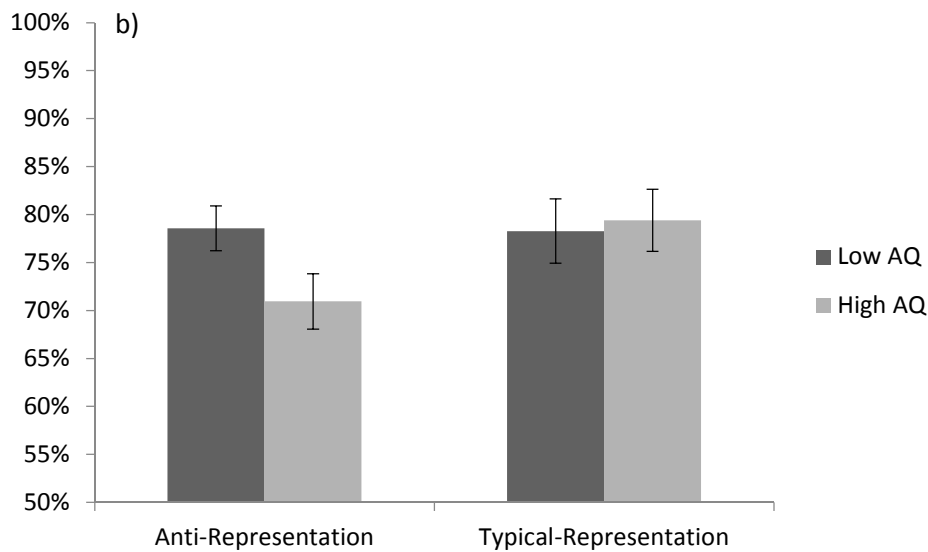
#### *Anti-expression adaptation task (3.3.5)*

The DV was the proportion of responses in the predicted direction the valence of the aftereffect that would ordinarily be expected arise from the adaptation stimuli based on previous research, rather than in terms of the valence of the adaptation stimuli themselves. For the Angry and Anti-happy expressions the perceptual aftereffect normally involves a positive valence, while the Happy and anti-angry expressions normally produce a perceptual aftereffect that is negative in valence. A repeated-measures ANOVA with the within-subjects factors of Aftereffect Valence (Positive vs. Negative) and Representation of Expression (Typical-expression vs. Anti-expression) and between-subjects factor of Group (High AQ vs. Low AQ) was used to analyse the proportion of responses in the predicted direction. In this analysis, only the 100% Anti-expression and Typical-expression adaptors were used. The 50% and 100% adaptation stimuli will be analysed separately subsequently.

There was no main effect of Group ( $F(1,90) = 2.65, p > .05$ ). There was a main effect of Aftereffect ( $F(1,90) = 12.78, p < .01$ ), with proportion of responses in the predicted direction for positive valence aftereffects being higher (82%) than negative valence aftereffects (71%). There was also a main effect of Representation ( $F(1,90) = 4.59, p < .05$ ), with higher proportion of responses in the predicted direction for Typical-expressions (79%) compared to Anti-expressions (75%).

The results showed an interaction between both Group and Aftereffect Valence ( $F(1,90) = 4.79, p < .05$ ), with the post-hoc  $t$ -tests showing a significantly lower proportion of responses in the predicted direction for the perception of negative aftereffects for the High AQ group compared to the Low AQ group ( $t(90) = 2.35, p < .05$ ). This was not the case for Positive aftereffects where the two groups did not differ ( $t(90) = -1.139, p > .05$ ; fig 3.10a). There was also a significant interaction between Group and Representation of Expression ( $F(1,90) = 5.23, p < .05$ ), and post-hoc  $t$ -tests showed that the High AQ group performed worse than the low AQ group when identifying expressions arising from Anti-expressions ( $t(90) = 2.75, p < .05$ ) but not Typical representations ( $t(90) = .70, p > .05$ ; fig 3.10b).





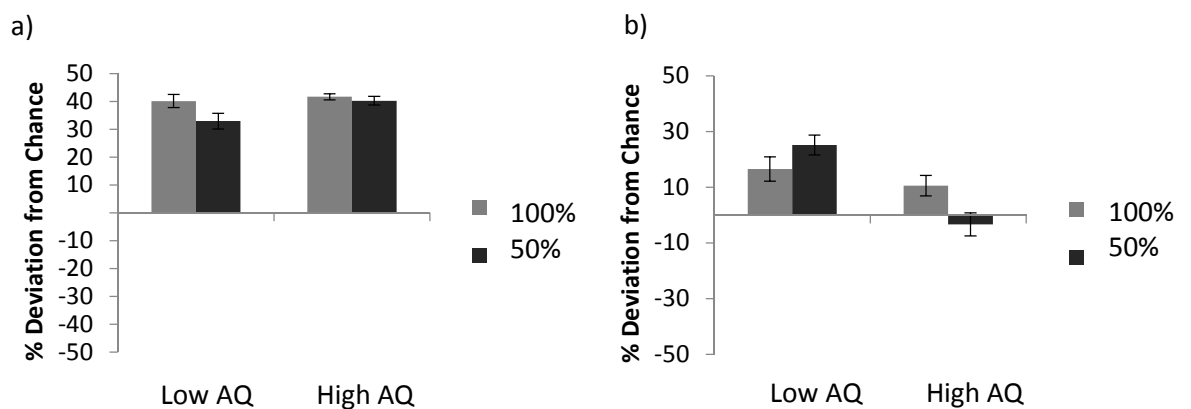
*Figure 3.10.* Bar graphs showing mean proportion of responses in the predicted direction for perceptions of (a) Negative and Positive aftereffect inducing adaptation stimuli and (b) aftereffects arising from typical- and anti-expression adaptation stimuli.

#### 50% vs 100% anti-adaptation stimuli

To help understand the differences in neural mechanisms that could be driving the difference found above, the differences in response to aftereffects following adaptation to Anti-expression representation stimuli of different representational strengths (50% strength vs 100% strength) were examined. A repeated-measure ANOVA was carried out on accuracy data, with Anti-expression (Anti-Happy vs. Anti-Angry) and Representation Strength (50% Strength vs 100% Strength) as within subjects factors and a between subjects factor of Group (High AQ vs. Low AQ). The results showed a main effect of Anti-expression ( $F(1,90) = 126.70, p < .05$ ), with greater proportion of responses in the predicted direction overall for aftereffects arising from Anti-happy Expressions compared to Anti-angry expressions. There was also a significant main effect of Representation Strength ( $F(1,90) = 16.56, p < .05$ ), with higher proportion of responses in the predicted direction scores for aftereffects arising from 100% Anti-representation adaptor strength versus 50% Anti-representation strength stimuli. A main effect of Group was also found ( $F(1,90) = 8.69, p < .05$ ), with the Low AQ group having higher overall proportion of responses in the

predicted direction than the High AQ group. No significant interaction effects were found with any factor (all  $p$ 's  $>.05$ ).

It is important to note the all-round poor performance in response to anti-anger expression stimuli by the High AQ group. A one sample  $t$ -test showed that this group performed no different from chance levels for anti-representations of Anger for both 50% ( $t(47) = -1.450$ ,  $p > .05$ ) and 100% ( $t(47) = -.06$ ,  $p > .05$ ) Representation Strength (Fig 3.11a, b). Taken in conjunction with the above results that show that the Low AQ group have significantly better likelihood of responding in the predicted direction on this task, it is pertinent to express that although statistically the High AQ group show an improvement in identification of aftereffects between 50% and 100% strength adaptation stimuli, for negative emotional expressions this is not a meaningful difference as is does not diverge from chance responding.



*Figure 3.11.* Bar graphs showing mean valence represented as a deviation from chance in the expected or unexpected direction for perceptions of aftereffects. Shown following adaptation to (a) anti-happy expressions (b) anti-angry expressions at both 50% and 100% adaptor strength.

## Discussion

The results of the current study showed that people with greater degree of ASC-traits had reduced ability than those with low amount of ASC-traits to perceive a resultant aftereffect as negative in valence following adaptation. No differences were found between groups for aftereffects typically perceived as positive. The current study suggests that the neural basis for representing emotional expressions in those with high ASC-traits is atypical, at least for representing negative valence expressions. These results are consistent with deficits reported for processing emotions with a negative valence in diagnosed ASC (Ashwin et al., 2007; Ashwin, Chapman, et al., 2006) and extend difficulties in processing negative emotions to the wider autism spectrum. Together these results show that there are difficulties for processing negative emotional expressions across the autism spectrum that stretches outside of those directly diagnosed with ASC.

The results from adaptation to 50% vs 100% anti-expression adaptor strength stimuli showed that both ASC-trait groups were better able to identify emotional expression aftereffects arising from 100% adaptors. Previous research has suggested that this is typical of a prototype-referenced, opponent coding model. Adaptation to stimuli with higher perceptual strength (i.e. further distance from the prototype average face) will lead to a greater perceptual aftereffect when exposed to the average face (Rhodes & Jeffery, 2006; Robbins, McKone, & Edwards, 2007; Skinner & Benton, 2010; Tsao & Freiwald, 2006). However, although the high ASC-trait group showed better perception of aftereffects in the predicted direction for aftereffects arising from 100% adaptor expressions compared to 50% adaptor expressions, their responses were not significantly different from chance levels for anti-angry expression adaption stimuli as would be predicted. This does not support the use of a prototype referenced system when representing negative emotional expressions.

An alternative account is the multi-channel or exemplar model. A multi-channel model suggests that exposure to an exemplar will suppress neuronal firing around the population that codes for that exemplar. This then leads to an aftereffect which repulses perception away from that exemplar. This means that the perceived aftereffect is stronger for stimuli

that are closer in perceptual space to the exemplar (see Tsao & Freiwald, 2006 for an overview of this concept). In the current study we would have expected the 50% strength adaptors to lead to a higher proportion of responses in the predicted direction if participants used a multi-channel model. However, this pattern of results does not typify the response seen in the high ASC-trait group suggesting no distinct evidence that they employ this alternative model of emotional expression representation.

When presented with negative emotional expressions individuals with high ASC-traits it cannot be determined whether the high ASC-trait group are using either a prototype referenced or a multi-channel model of emotion expression representation. This suggests an under developed representation of emotional expressions in this group. Instead it is likely that this group is using a compensatory mechanism. Research with individuals with an ASC diagnosis showed that adults with ASC are more likely to use a rule-based system when identifying emotions (Rutherford & McIntosh, 2007). This may also be the case with those with high degree of ASC-traits from the general population. Although Rutherford and McIntosh's (2007) result was found regardless of valence, subclinical individuals from the WAS with a high number of ASC-traits may be using an alternative strategy to judge negative emotional expressions. It is suggested that one of these alternative strategies is a rules-based strategy, where the individual identifies emotional expressions based on learnt rules that govern them. For example, a happy expression may have up-turned lip corners whereas an angry expression may have furrowed eyebrows. A rules-based strategy for face processing is slow and deliberate and doesn't necessarily use an adaptive representational system as it relies on learnt rules to make a judgement. This explanation is possible, as people with high ASC-traits and those with an ASC diagnosis are more likely to use a systemising approach to understand the world which involves observing patterns and rules in the environment (Baron-Cohen, 2002, 2006a, 2006b, 2009). In this case systemising would mean identifying the patterns in facial expressions that lead to a predicted output and using these to interpret the social world. Further research into compensatory strategies and how people with high ASC-traits in the WAS view and interpret faces is necessary in order to understand the spectrum approach to ASC fully.

Further to this, the results also revealed that the high ASC-trait group performed poorly when identifying aftereffects arising from anti-expression adaptation stimuli in general when compared to the low ASC-trait group. Anti-expression stimuli were created to explore how typical individuals represent emotional expressions on a neural level and specifically whether emotional expression processing used a prototype referenced system. The poor



performance of the high ASC-trait group when assessing the valence arising following adaptation to anti-expressions may be indicative of a differences in how the brain based mechanism for emotion expression processing has developed in these individuals. This would be expected by the social motivation theory of ASC as this would suggest that a lower drive to attend to the social world would lead to underdevelopment in the brain areas associated with emotion expression representation. This interpretation is consistent with brain imaging research in those with ASC that has shown differential brain activation for emotion processing (Ashwin et al., 2007). This helps to support the spectrum approach to ASC by showing a consistent pattern of similar difficulties present in a diagnosed population and the higher end of the WAS. However, there are currently few investigations into brain based differences and compensatory strategies for emotion processing in the WAS and direct comparisons between diagnosed individuals and those in the WAS cannot currently be made.

Adaptation to emotion expressions has been previously examined in ASC finding an ASC difficulty for identifying emotion expression aftereffects (Rutherford et al., 2012). Rutherford et al., adapted ASC participants to typical-emotional expressions and allowed them to choose typical emotional expression labels to judge the aftereffect. However, the opposite of a typical emotional expression does not necessarily correspond with an emotional label. The current study explored representation of expressions in a sample of typical individuals with high and low ASC-traits by using anti-expression stimuli that have been shown to lead to readily identifiable afterimages (Skinner & Benton, 2010). In addition to this, the current study adapted participants to typical-expressions, but rather than ask them to label the aftereffect they create, participants were asked to judge the resulting valence of the aftereffect. This method avoids participants having to give specific labels to the aftereffects which simply do not exist when inducing aftereffects arising from typical-expressions. The results from the current study support Rutherford et al., (2009) by showing similar issues with representing emotional expression information exist at the high end of the typically developing spectrum of ASC-traits. However, to draw more meaningful conclusions, a similar study that uses anti-expressions should be conducted with individuals with ASC in order to rectify the limitations present in Rutherford et al., (2009).

An alternative interpretation that is in line with the social motivation theory could be that in those with high ASC-traits, the aftereffects produced by adaptation do not achieve a similar perceptual strength as they do in people with fewer ASC-traits. This explanation does not suggest a completely different neural mechanism or compensatory strategy for

emotional expression representation in high-trait individuals, but instead suggests an impairment which leads to a weaker perceptual representation. This would be predicted under a social motivation framework as these individuals would be suggested to have poorer development of the brain areas that create perceptual representations due to limited experience in life. The aftereffects arising from adaptation are mild expressions and if they are milder for participants with high ASC-traits due to an under developed representational system, this could lead to ambiguity and identification difficulties. This explanation fits with the spectrum approach to ASC as it suggests a gradient of ability that runs throughout the population and people with ASC would be expected to show even poorer performance in a similar task. In support of this, people diagnosed with ASC have been shown to be impaired when asked to identify mild negative emotional expressions (Law Smith et al., 2010), this difficulty with mild representations could well extend to autism traits in the general population. Indeed, Poljac et al. (2013) have found a need for greater facial emotion information in high ASC-trait individuals in order to correctly identify facial expressions. Additionally, the high ASC-trait group showed chance performance for negative aftereffects regardless of the original adaptation stimuli strength. This suggests that the system underlying emotion expression representation may not have developed to the same extent as those with fewer ASC-traits.

There are some limitations to the current study. Participants were only allowed to make a binary assessment of the aftereffects as either positive or negative in valence. This was done for two reasons. Firstly, it allowed the current study to address some issues in previous research (e.g. Rutherford et al., 2012), as we were able to present typical-expressions but still offer participant a valid response system. Secondly, using valence labels was preferential to using emotive labels such as 'happy' or 'angry' as it reduces the confound that may arise when dealing with a population who may have difficulty with these verbal labels. Although it was necessary to account for this by using a binary choice, richer data could have been achieved through allowing participants to judge the specific emotion created by an aftereffect. This would have allowed the ability to assess specific differences in how the current population perceived aftereffects of anti-expressions. This was not used as it would have led to withdrawal of typical expressions as adaptation stimuli as the aftereffects they produce do not have a specific, quantifiable label. In addition to this, participants were not offered the choice to respond to the probe image as 'neutral'. This meant that chance-level results (50% proportion of responses in the predicted direction ) were used to imply that adaptation did not take place. Allowing participants to

respond with a 'neutral' option may allow the chance to directly assess whether an adaptation effect has occurred, but participants may also miss the subtlety of the illusion and overuse this response option. This is a methodological point that would, ideally, need to be explored in order to provide further visual adaptation research with the best tools available for assessing the adaptation effect.

Further to this, although the high ASC-trait group performed comparatively poorly when responding specifically to the negative aftereffect produced by adapting to typical-happy expressions, they still performed well above chance. The aftereffect created by a typical-happy expression will not map directly onto any specific negative emotion, but has been shown to look negative in valence. This result does suggest that this group may be able to produce negative representations of emotional expressions, but cannot do so effectively when presented with anti-expressions as seen in the analysis. This suggests that, in some respect, there is some level of functional neural coding mechanism underlying the perception of emotion, it perhaps just doesn't operate in a typical manner or isn't an expert system that can accommodate all variants of emotion. This could also be a sign that the neural mechanisms underlying the prototype referenced system of positive emotional expressions is intact.

Finally, this was a subclinical group of people, and so the research needs to be tested in those diagnosed with autism to test if similar results are seen. Although there has been some research that suggests a similar pattern of results in those with ASC (Rutherford et al., 2012) future work is needed in this area.

In conclusion, the current work shows that people who have high traits of ASC do show a similar pattern of social-cognitive abilities that would be expected in individuals with a diagnosis of ASC, but only once the neural mechanisms for emotion expression processing are assessed. These differences can easily go unnoticed without exploration to a deeper level of perceptual ability, possibly due to advanced compensatory techniques developed in this group. It has been suggested here that those with high ASC-traits may normally use alternative strategies to aid their emotion recognition ability and therefore are able to compensate for any representational deficit. The current results suggest that the social motivation theory may apply to those with high ASC-traits in the general population. By exploring the neural mechanisms of social-cognitive behaviour in groups that are analogous to clinical populations, we may be able to uncover the basis for the deficits that are apparent in ASC and related disorders.

## **Chapter 4 – Study 2**

### **Using the dot-probe paradigm to study attention mechanisms to emotional faces in the Wider Autism Spectrum.**

#### **Introduction (4.1)**

Atypical emotion expression processing is likely characteristic of people at the high end of the WAS, however work in this area is limited. The previous study found that there was a deficit for those with a greater number of ASC-traits to form representations of negative emotional expressions. It was suggested that a deficit in the neural mechanisms that code for negative emotion expressions may exist in this group. A deficit in representing emotions, as seen in study 1, could arise due to a limited experience with emotional expressions throughout life compared to those with fewer traits as would be expected by the social motivation theory of ASC. One way that people with high ASC-traits may have lacked experience with emotional expressions is through not paying typical attention to them in their day-to-day life. The following chapter critically reviews paradigms for exploring attention based atypicalities. Following this, an investigation into attention for emotional expressions in groups of individuals with high and low ASC-traits is reported. The results are discussed in terms of the similarities and differences seen in the WAS and diagnosed ASC.

#### **Attention Tasks (4.2)**

Attention, the process of consciously or unconsciously shifting awareness to aspects of the environment, can allow insight into which features of the environment are most salient for an individual. Attention is a key issue to consider when assessing any neuro-developmental condition. Early differences in attention during development have been suggested to affect the developmental pathways that lead to the formation of important mechanisms (Chevallier et al., 2012). The mechanisms underlying attention, the processes that drive it and how this relates to behaviour have been a topic of scientific investigation for the past 35 years. There are several ways of assessing attention. Popular methods include the modified stroop tasks, eye-tracking tasks, tests of directed attention and visual-probe tasks. Each task has its strengths in assessing a certain aspect of visual attention.

#### *Modified Stroop Task (4.2.1)*

The modified stroop task is based on the original stroop task in which participants are presented with a series of words that are the names of colours. Participants are required to name the colour that the word is printed in and not read the word itself. When the task is incongruent, and the colour name is different to the colour it is printed in (e.g. “red” printed in blue), participants suffer interference (Stroop, 1935). In order to complete the task, participants have to inhibit word reading while attempting to name the colour it is printed in. When this incongruence occurs, participants take longer to be able to identify the colour of the word. One explanation for this is that participants are required to selectively attend to the colour of the text while inhibiting word reading. When people fail at this task, this can be seen as either greater attention allocation to the text or poor inhibition of task irrelevant information. The modified stroop paradigm builds off this, but frequently uses coloured emotional words (Gotlib & McCann, 1984) or coloured overlays on top of images (Ashwin, Wheelwright, et al., 2006) in order to assess attention. For example a pictorial version of the emotional stroop uses images of emotional expression faces presented behind coloured overlays. A participant has to identify the colour of the overlay while ignoring the image presented on the screen. Reaction time for this task is measured and slowed reaction to emotional expression trials indicate that attention was grabbed by the stimuli presented behind the overlay on those trials. This task is useful for determining whether an individual’s attention is inappropriately captured by emotional expression stimuli.

#### *The Visual Probe Task (4.2.2)*

The visual-probe task created by Posner (1980) measures directed visual attention. The task involves using a cue to direct attention towards one side of a screen or another. Following this, a probe (such as a dot) appears in either the cued location or the non-cued location. Participants are then required to respond to the probe as quickly as possible. Individuals are typically faster to respond to correctly cued probes and this paradigm was the first to show that attention is allocated prior to the explicit direction of attention through eye or head movements. This task can be modified to explore social attention and attention for emotional expressions. By replacing the arrow cue with a face that is looking to the left or right of the screen, the Posner task can assess whether attention directed by social stimuli are able to influence individuals attentional allocation (Bayliss & Tipper, 2005). Further to this, the face that is cueing the probe can be displaying an emotional

expression. By displaying an emotional expression on the cueing face, research can determine whether participants are more likely to follow a social cue when it may represent that something important is about to occur. For example, Hietanen and Leppänen (2003) used schematic emotional expressive and neutral faces to cue attention finding that in typically developing adults attention is directed more by expressional faces than neutral faces regardless of which emotion they are displaying. Further to this, Mathews, Fox, Yiend, and Calder (2003) used images of actors displaying emotional expressions and found that for people with higher levels of anxiety, gaze was directed quicker when cued by a fearful face. This shows that expression information does guide attention, and that this differs depending on the relevance the expression has for the individual. This supports other research in the individual differences literature which has shown that people with clinical anxiety are quicker to respond to a probe that has been correctly cued by a fearful face and take longer to respond to a probe that had been incorrectly cued by a fearful face (Matthews et al., 2003). Evolutionarily, it is advantageous to attend to others displays of emotion as this could communicate other social information such as the presence of others or warn of potential danger in the environment.

#### *The dot-probe paradigm (4.2.3)*

MacLeod, Mathews, and Tata (1986) developed a visual-probe paradigm, the dot probe, by building upon the previous attention allocation research. The dot-probe paradigm was created to assess attentional allocation between two different stimuli and the knowledge that people will respond faster to a location that they are attending to. The dot-probe paradigm was originally used with individuals who had been referred for anxiety treatments. In this task, participants are presented with trials containing two words in opposing corners of a screen. One of these words is neutral and the other is disorder related (in this case a threat related word). During this task, participants are instructed that they are to respond to a probe that will appear on the screen in the place of one of the words. Participants' response times are measured in order to see whether attention allocation differs between words that have a negative or neutral valence. MacLeod et al. (1986) found that socially anxious individuals were faster at responding to probes that replaced disorder-related threat words than those that replaced neutral ones. This was interpreted to mean that, due to issues that were present across the life span of the socially anxious individuals, attention is allocated towards stimuli that are related to their disorder. This could be an initially advantageous behaviour as it would help these individuals detect and avoid situations of threat which heighten their anxiety. However,

this behaviour is then suggested to become maladaptive as socially anxious individuals increasingly attend to these adverse stimuli which can heighten arousal and anxiety further. This is suggested to be an underlying factor in cause or maintenance of the disorder.

The visual-probe procedure has since been developed further to show that disorder related biases can be found across different mediums. For example, when replacing text stimuli with non-word image stimuli which are more realistic and present in the participant's environment, people with clinical levels of social anxiety continue to show a bias towards threatening stimuli relative to controls. This was shown through the use of emotional faces which paired displays of threat stimuli (angry expressions) or non-threat stimuli (happy expressions) with neutral face expression stimuli. Participants with social anxiety and non-clinical individuals with high traits of social anxiety were shown to have a bias in their attention allocation for the threat based stimuli (Bradley, Mogg, Falla, & Hamilton, 1998; Bradley, Mogg, & Lee, 1997; Bradley, Mogg, White, Groom, & De Bono, 1999). The shift in the literature towards using stimuli that are ecologically valid depictions of threat is important as the systems underlying the detection of threat could be based in biologically reactive mechanisms (such as flight or fight; Ohman, 1996), which would respond better to realistic depictions of threat rather than arbitrary symbols such as text. Additionally, the systems involved in attentional allocation are thought to be biologically driven by the amygdala, one of the neural centres implicated with directing attention to salient emotional and threat related environmental stimuli (Damasio, 1994, 1999; Vuilleumier, 2005). Theoretically and empirically derived links between processes of inappropriate attentional allocation and specific neural systems are important in order to appreciate and understand both the potential origins of deficit behaviour and the later cognitive processes that allow the behaviour to arise and propagate.

#### *The Cognitive-Motivational Theory (4.2.4)*

The cognitive-motivational theory of attention bias (Mogg & Bradley, 1999) attempts to explain attentional bias behaviour by suggesting that attention biases arise due to the importance stimuli are awarded by each individual. This theory posits that an internal Valence Evaluation System assesses the importance and threat value of external stimuli. Stimuli that are important and high in threat value are highlighted by the Valence Evaluation System and attention is directed towards that stimulus. This allows the individual interrupt their current goals and pursue a line of action that preserves their

safety. This theory suggests that those with high anxiety are likely to have a lower threshold before their Valence Evaluation System (VES) identifies a stimulus as threatening. Whereas someone with low levels of trait anxiety are no more likely to attribute high levels of threat to a negative emotional expression, those with high trait anxiety and have had recurrent issues with negative emotional expressions throughout life are more likely to attribute threat to negative emotional expressions. For high anxiety individuals, the Valence Evaluation System will direct attention for negative emotional expressions more readily than for people who have not had such negative experience. This theory is useful as it helps to explain how people differ in their attentional response to external stimuli through the use of an adaptive mechanism.

This theory links biological substrates such as the amygdala to cognitive mechanisms which include previous experience. The amygdala is thought to rapidly direct attention towards crude external representations of threat that have developed over the period of evolution. This is then complimented by contextual information provided by previous experience and personal knowledge. The VES integrates all this information in order to make a judgement on threat level and guide attention towards external stimuli when it exceeds the necessary arousal level. Through the implication of the amygdala as one brain region implicated with inappropriate attention, it is possible to appreciate how inappropriate attention for social and emotional expression information may arise in ASC and the wider autism spectrum.

However, the social motivation theory posits that some of the aberrant behaviour seen in autism could be a result of atypical attention mechanisms possibly arising from the amygdala (Ashwin et al., 2007; Baron-Cohen et al., 2000; Chevallier et al., 2012). Atypical amygdala function could lead to a *lower* drive to attend to social and emotional information present in the environment. In turn, this would lead to affected individuals having less experience with social and emotional information and developing atypical social communication. The social motivation theory of ASC would predict lower attention for emotional expression information in ASC and those with high ASC-traits when assessed using a visual-probe paradigm whereas the cognitive motivation theory would predict a bias *for* emotional expression information in these populations. The dot-probe method could be a useful tool for assessing differences in attention which may exist in ASC and the WAS and testing the social motivation theory of ASC.

Focusing on attention to emotional expressions is a key area that hasn't been fully addressed in ASC or the WAS. People with ASC are documented to have less ability to



correctly interpret negative emotional expressions (Ashwin, Chapman, et al., 2006; Celani et al., 1999; Law Smith et al., 2010) and this normally leads to difficulty in day to day life. Issues with negative expression information exist to a lesser extent in the WAS (Poljac et al., 2013). Given how tightly emotional information processing is linked to attention and the amygdala, exploring the attentional processes that underlie difficulties with emotional expressions in ASC and the WAS may help us understand where emotion expression processing impairments arise from, how these impairments later bias an individual's attention and how adequately the social motivation theory can explain ASC and the WAS.

### **Visual-probe in ASC and the WAS (4.3)**

To date, only three studies have been found to have used a visual probe task to explore the underlying attention mechanisms towards social behaviour in ASC (Bar-Haim, Shulman, Lamy, & Reuveni, 2006; Hollocks, Ozsivadjian, Matthews, Howlin, & Simonoff, 2013; Moore et al., 2012). All three of these studies have assessed different aspects of social information processing; each has arrived at different conclusions. Moore et al., (2012) assessed attention towards social vs non-social stimuli in adults with ASC using both subliminal and supraliminal display timings. This study's findings supported the social motivation theory finding that at the supraliminal level, where participants are aware of the stimuli they are being presented, typically developed controls show a bias for face stimuli whereas no such bias is seen in those with ASC. Further to this, neither those with ASC or Controls show a bias for face information at the subliminal level. This suggests that the facial stimuli have to be consciously perceived in order for it to draw attention over non-social aspects in typically developing individuals. A limitation here, however, is that Moore et al., (2012) presented face stimuli alongside non-face stimuli which included cars and houses. These stimuli were chosen for their face-like features but not for luminance and contrast. It is difficult to say that the effect found in Moore et al., was not driven by low-level visual effects

Dot probe studies exploring issues with social attention in ASC have also attempted to assess whether specific features of the face capture more attention than others. When people with ASC do attend to the face, they have been shown to preferentially focus to the mouth region of the face and less on the eye region (Klin et al., 2002, Although recent research suggests more of an overall face scanning impairment; Chawarska & Shic, 2009; Pelphrey et al., 2002; Snow et al., 2011). Bar-Haim et al., (2006) explored attention towards

the eye and mouth region using an adapted version of the visual-probe paradigm. This study presented participants with only one stimulus on each trial (a photograph of an entire face) and varied the location of the probe to appear either at the eye or mouth region. Bar-Haim et al., found no difference in attention bias towards the eye or mouth region of the face between people with ASC and control participants. Unfortunately the modifications to the task made by Bar-Haim et al., may not have had the sensitivity to detect differences in attention as the study was very far removed from the traditional probe-detection task. For example, although the areas of interest (eyes and mouth) were presented at opposing points on the screen, they were presented as part of a single stimulus (an entire face). Traditionally, two separate stimuli are presented simultaneously on the screen and compete for attention allocation. There is no certainty as to the extent this is replicated when the stimuli are presented embedded into a gestalt, whole image. A further issue with using an entire face is that the stimuli cannot swap positions without flipping the face stimuli upside down. Upside down faces have been consistently shown to be viewed in a different manner to upright ones. Upside down faces may not be processed as a gestalt image, but instead processed in a piecemeal way (Farah, Wilson, Drain, & Tanaka, 1998; Valentine, 1988). Therefore inverted face stimuli may be too different to be compared to upright faces for the sake of attention based research. Further to this, the stimulus was not removed from the display before presenting the probe and remained there after the probe had been removed. This makes the attention mechanisms of orienting (attending towards a stimulus) and disengaging (the ability to move attention from a stimulus) difficult to disentangle. As this is not a typical set up for a visual-probe study the results hard to interpret in the light of previous visual probe research. The methodological issues could be the reason for the null finding in this study as they could obscure any potential differences in the two groups' performance.

More pertinent to the current project is the work by Hollocks et al., (2013). Hollocks et al., conducted a visual probe study on children with ASC in order to assess attention biases to emotional faces and words, and how this related to levels of social anxiety in ASC. Social anxiety is important to measure during visual-probe tasks because, as noted above, people with high social anxiety have been shown to have attentional biases towards threat related faces which, when exploring social and emotional attention in relation to ASC could be a confounding variable (Bradley et al., 1997; Bradley et al., 1999). Hollocks et al., found that children with ASC did not show an increased attention bias to threat or non-threat stimuli regardless of the levels of anxiety they displayed. This result was somewhat unexpected

given that anxiety normally directs attention towards threat. However, this does support the social motivation theory as it would predict that the ASC group would have lower levels of attention regardless of social anxiety. It would be assumed that deficits in the systems that drive attention in this group would be under developed which could hinder the VES. Another explanation is that, perhaps due to the comorbidity in Hollocks et al's sample (and in ASC in general), the effects of social anxiety may not have been effectively teased apart from ASC in this study.

Previously, there has only been one study examining individual differences relating to ASC as a factor that may affect attention towards emotion expression information in the typical population (Ribeiro & Fearon, 2010). This study assessed Theory of Mind (ToM) ability through the Eyes task (Baron-Cohen et al., 1997). ToM is the ability to understand that other people have a mental state that could differ from your own. A crucial part of ToM is being able to attribute others behaviour and expressions to thoughts, beliefs and mental states. The Eyes task explores this well by presenting participants with cropped images showing only a model's eye region and asking them to judge how the model in the image may be feeling. Poor ToM ability is a marker of poor social ability and people with ASC and high ASC-traits often score poorly on tests of ToM compared to typical individuals or people with fewer ASC-traits (Baron-Cohen et al., 2001).

Ribeiro and Fearon found a trend showing that those with poor ToM skill were more likely to preferentially attend to negative emotional expressions in a visual-probe task than either positive expressions or neutral objects. In line with what is expected from a cognitive motivational approach, the authors suggest that the results could represent a lifetime of issues with threat related stimuli in those with low ToM. In this case, not knowing how to best interpret negative expression stimuli which could often have a range of different meanings could in turn lead to negative expressions having extra salience. The authors suggest that vigilance for negative emotions would help those with poor ToM skill to selectively attend to the faces in the environment that give them the most problems, and therefore allow a greater processing time for these stimuli. The cognitive-motivational approach, however, would suggest that this bias arises due to negative stimuli being more arousing to the VES of low ToM individuals. Although this is a good preliminary starting point for research in this area, there are methodological issues in this study which prevent it from being able to inform regarding attention mechanisms in the VES. For example, the stimuli used by Ribeiro and Fearon (2010) involved pairing the emotional stimuli of interest to common objects. This means that other, basic perceptual features of the face

and non-face objects could be driving the effect (a complete discussion of these factors follows subsequently). In addition, this study primarily assessed social attention in general rather than being able to pick up on subtle differences in attention as it applies to emotion expression information. To remedy this, the procedure should match emotional faces with other non-emotional faces as in previous studies examining attentional allocation to emotional expressions rather than pairing with non-face stimuli (i.e. Bradley et al., 1998; Bradley et al., 1997; Bradley et al., 1999; Hollocks et al., 2013). Finally, a measure of ASC related traits, rather than a proxy measure (ToM), would help explore potential differences in attentional mechanisms across the WAS.

#### **Methodological considerations (4.5)**

There are methodological considerations when using the dot-probe task to assess underlying attentional biases. Aspects such as how the visual information is presented, display time of the visual attention stimuli and the response options regarding the probe are important considerations.

##### *Probe detection (4.5.1)*

Early versions of the visual-probe task employed a probe-detection response. Probe-detection, as suggested by the name, simply requires the participant to detect the presence of, and respond to, the position of the probe on the screen. This is typically a binary set of options such as left versus right or top versus bottom. This task is relatively simple and does not add any additional cognitive load in order to complete the task. However, this task is susceptible to bias monitoring strategies. When a task requires such simple requirements, participants can potentially look purely at one half of the screen and simply respond regarding the presence or absence of the probe at that location. One way to avoid this is to have the probe absent on a percentage of trials. One issue with this is that probe detection tasks already contain a large number of trials (in the hundreds or thousands). Adding up to 25% more trials in order to overcome bias monitoring strategies comes at the cost of increased participant fatigue.

##### *Probe Classification (4.5.2)*

In order to overcome bias monitoring techniques without needlessly increasing the number of trials necessary for the completion of the task, probe-classification responses were designed by Macleod and Chong (1998; cited in Mogg & Bradley, 1999). Probe-classification

tasks move away from simply presenting a uniform probe type and instead present the participant with a pair of vertical (:) or horizontal (..) dots. This task requires participants to respond to the orientation of the target rather than its raw position on the screen. The benefit of this task is that participants need to monitor the entire display equally. One downside of this technique is that it increases the task complexity and the variability in the reaction time and accuracy for each participant also increases. An empirical test of the probe-classification task against the traditional probe-detection task has shown that, although there is indeed evidence for increased variation of responses in the classification task over the raw response task, the classification task retains its sensitivity for detecting attention biases in clinical populations (Mogg & Bradley, 1999).

#### *Timing considerations (4.5.3)*

The classic visual-probe studies typically used stimuli display timings between 500-1000 ms (Bradley et al., 1998; Bradley et al., 1997; Bradley et al., 1999; Mogg & Bradley, 1999). Studies have explored the use of different stimulus display durations by examining the effects of presenting stimuli for shorter periods of time than were used in the original visual-probe studies. The presentation of shorter durations was originally employed due to a confusing finding in the literature. The threat bias found in people with high anxiety was not replicated to any extent in typically developing populations. This is despite other paradigms suggesting that there is indeed an attention preference for threatening stimuli which purportedly exists as a survival instinct (Ohman et al., 2001). Research using attention stimuli display timings of 100 ms have found that attention towards threat is indeed present in typically developing individuals at this level. What is not certain is whether this effect is, in fact, increased attention for threatening stimuli as suggested by evolutionary arguments, or operates through inhibition of less threatening stimuli at shorter time scales (Cooper & Langton, 2006). Any interpretation of visual-probe tasks in the general population must be undertaken conservatively, as there is evidence that the results gleaned can be unreliable (Schmukle, 2005; Staugaard, 2009).

In addition to shorter stimuli display timings revealing attention differences in the typical population, they can also help inform which aspect of attention are abnormal when individuals show differences in attention patterns on visual-probe tasks. There are two different component of attention: orienting and disengaging. When using only one stimulus duration it is difficult to understand whether differential attention represents a heightened propensity to orient towards a stimuli, or a difficulty in disengaging attention from a

stimuli. However, this issue is difficult to address in ASC as research has found that those with ASC have delayed orienting for stimuli in general (Townsend, Harris, & Courchesne, 1996). Using shorter stimuli presentation durations may not lead to an accurate reflection of engagement and disengagement profiles, at least when compared with typically developing controls.

#### *Stimuli considerations (4.5.4)*

Finally, it is important to control the stimuli used to capture attention in this task. Many different factors can influence attention. For example, luminance, contrast and novelty all play a role in attention capture. Images must therefore be matched on these aspects. This can be completed digitally through using software that allows for assessment of mean luminance and contrast. However, when assessing luminosity and contrast this way, the mean output value is not necessarily representative of the overall perceptual effect. For example, one image may have an even luminosity profile, while another may have patches of increased luminosity (and therefore contrast). Additionally, to correctly control for this, specialist luminance measuring hardware is required. It is preferable to match the structure of the images. When conducting facial expression research, this is relatively simple. By choosing models that are matched by identity and do not show features in one image that are not present in other images (i.e. teeth), any luminosity and contrast should be relatively consistent across images. However, in emotion expression research this can be difficult as areas of high contrast could be important when assessing what draws attention to that expression. In addition to this, to avoid task irrelevant distractors, images can be edited to exclude non-expression information such as hair and ears.

#### **Aims and hypotheses (4.6)**

Study 2 aimed to investigate whether (1) the mechanisms underlying attention to emotional expressions differed between people with high vs low ASC-traits and (2) whether this was different for positive vs negative emotional expressions.

Based on previous research, it is hypothesised that those with greater ASC-traits will have a different attention allocation to negative emotional expression stimuli than those with low-ASC-traits (Ribeiro and Fearon; 2010). The cognitive-motivational approach hypothesises that (1) people with high ASC-traits would be expected to show a bias for emotional expressions and further to this (2) as negative emotional expressions tend to cause more

difficulty for this group, a larger bias will be found for negative emotional expressions than positive ones. Alternatively, the social motivation theory hypothesises that (1) people with high ASC-traits will have a reduced attention bias to emotional expression compared to controls and (2) this should not differ for negative or positive emotional expressions.

## **Method (4.7)**

### *Participants (4.7.1)*

The same participants as study 1 took part in the current study, meaning that there were 94 Participants in total (48 female, mean age = 28.28 years, SD = 8.18). A quartile split was conducted with Participants with the lowest 25% of AQ scores forming the low autism trait group (n = 25; 11 female, mean age = 29.36 years, SD = 8.50; AQ < 14, mean AQ = 10.76), and those with the highest 25% of AQ scores forming the high autism trait group (n = 24; 12 female, mean age = 27.25 years, SD = 8.14; AQ > 22, mean = 26.83).

### *Stimuli (4.7.2)*

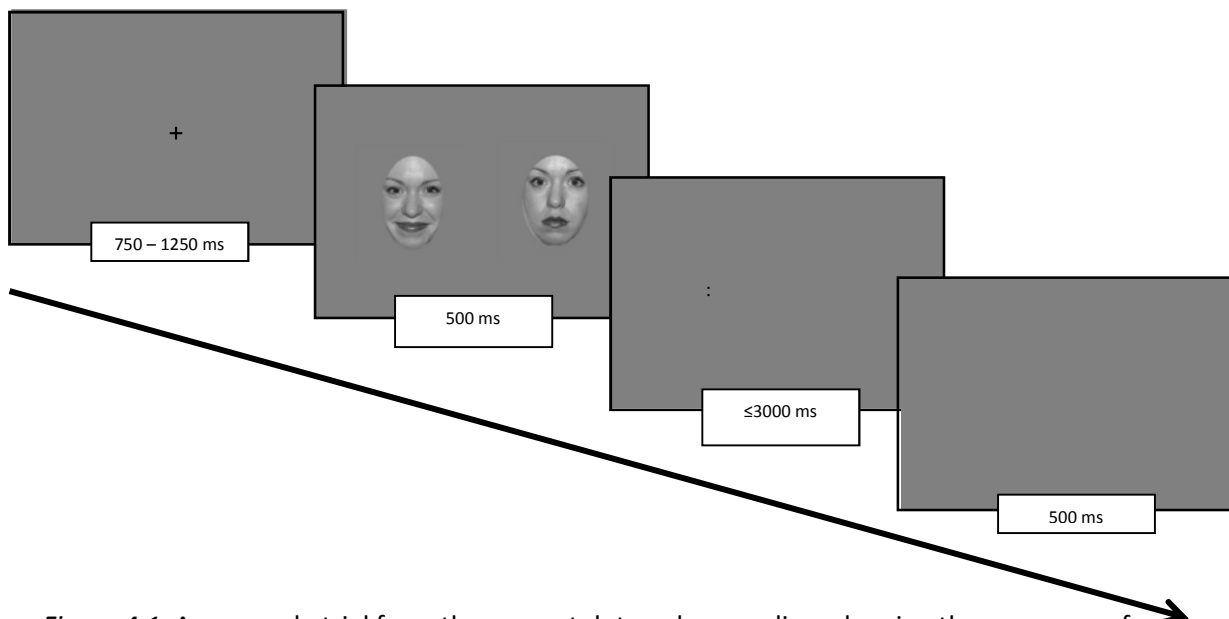
Images of 8 male and 8 female actors displaying emotion expressions were selected from the NimStim database (Tottenham et al., 2009). For each of the 16 actors, images expressing happy, angry and neutral were used, resulting in 48 different images in the study. The face stimuli were cropped to fall within the same oval shape, in order to remove hair and background information. All images were 280 x 385 pixels in size and were converted to greyscale. Images were matched for average luminosity. Target stimuli consisted of two dots that were either horizontal (..) or vertical (:) in their orientation. The dots were presented in 12 pt Courier New Bold font on a visual display unit with a resolution of 1280x1024.

### **Procedure (4.7.2)**

Participants were sat in a dimly lit room and positioned at a desk with their eyes approximately 57 cm away from the centre of a computer screen. Ten practice trials preceded 256 experimental trials. These were presented in random order, with half the trials containing Happy-Neutral expression stimuli pairings and the other half containing Angry-Neutral expression stimuli pairings. The actor displaying the expression was consistent within each pairing; this allowed identity to be matched across images in each trial and allowed low level perceptual differences between stimuli to be kept to a minimum. The positioning of all stimuli was fully counterbalanced, with each image occurring equally as often on both sides of the screen. The probe also appeared an equal number of times behind all image types and on both sides of the screen.



Each trial began with a fixation cross presented in the centre of the screen. The fixation cross had a display timing that ranged between 750 and 1250 ms, (mean of 1000 ms). This was implemented to reduce rote responding and anticipatory behaviour during the study. Following the fixation cross, a pair of face stimuli were presented for 500 ms. The face pairs were presented with their centre at the middle of the vertical y-axis of the screen and at the 25% and 75% horizontal x-axis positions (corresponding to 320x512 and 960x512 pixel locations on a 1280x1024 visual display resolution). Stimuli were presented with 9.5 degrees of visual angle distance between their inner edges. A probe was presented in the centre location of one of the face pairs immediately after their presentation (fig. 4.1).



*Figure 4.1.* An example trial from the present dot-probe paradigm showing the sequence of images and timings for each display.

Participants were required to use the arrow keys on the keyboard to make their response. The keys were labelled with the up arrow representing a vertical response (:) and the right arrow representing a horizontal response (. .). Participants were required to discriminate the orientation of the probe as either vertical or horizontal. The probe remained on the screen until the participant made a response or until the maximum period of 3000 ms was reached, after which time the trial ended. At the end of each trial there was a 500 ms inter trial period before the start of the next trial.

## Results (4.8)

An independent-samples *t*-test showed the low and high ASC-trait groups did not differ on age ( $M = 28.33$ ,  $t(47) = 0.88$ ,  $p > .05$ ), and a chi-square test revealed no differences between groups for sex-ratio ( $\chi^2(1, N = 49) = 22.52$ ,  $p > .05$ ). As expected there was a significant group difference in the number of ASC-traits ( $t(47) = -4.01$ ,  $p < .01$ ) and LSAS scores ( $t(47) = -4.12$ ,  $p < .01$ ). In addition to this, LSAS scores correlated with AQ total ( $r(47) = .58$ ,  $p < .001$ ) and all subscales of the AQ, barring attention to detail (all other  $p$ 's  $< .05$ ).

RT data for the correct response trials were retained for analysis, except for response latencies below 200ms or above 1200ms which were removed as outlier scores. This resulted in the removal of 4% of the data. An independent samples *t*-test revealed there was no group difference in the number of incorrect responses in the task ( $t(47) = -.66$ ,  $p > .05$ ). The groups also did not differ in the number of RT-based outliers removed from the data ( $t(47) = -.92$ ,  $p > .05$ ).

Following this, each participant's median RT score was calculated for each condition. Mean values can skew reaction time data when even only a few of the scores are grossly different from the participants average. Median RT data were therefore used because this measure of central tendency is less susceptible to positive skews in the data (Whelan, 2010). Here it is important to note that there was no evidence of a speed vs accuracy trade off for either the High (Happy:  $r = -.091$ ,  $n = 23$ ,  $p > .05$ ; Angry:  $r = -.071$ ,  $n = 23$ ,  $p > .05$ ) or Low (Happy:  $r = .147$ ,  $n = 24$ ,  $p > .05$ ; Angry:  $r = -.292$ ,  $n = 24$ ,  $p > .05$ .) AQ groups

To simplify the analysis, bias scores were created for both groups. To create a bias score, each participant's reaction time score for trials where a probe followed emotional expressions was subtracted from their score for trials where a probe followed neutral expressions (Mogg & Bradley, 1999). This created a score of 0 if there was no bias, with positive scores implying an attentional bias towards emotional faces and negative scores suggesting a bias away from emotional faces (i.e. towards neutral faces). This was completed for both the positive and negative valence trials (see Table 6.1).

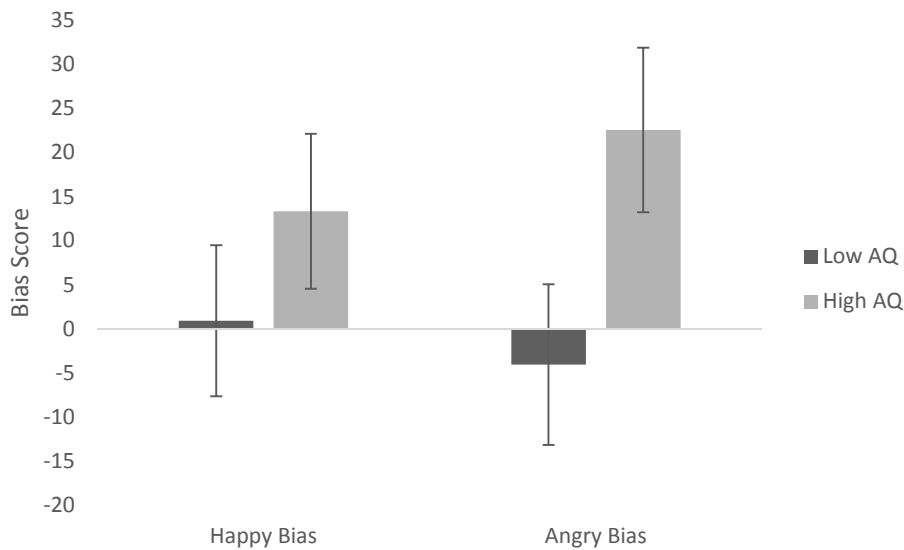
Table 6.1.

*Demographic data and emotion bias scores for High and Low Autism Trait Groups.*

Demographics		
and scores	Low Autism Trait	High Autism Traits
Mean AQ scores	10.76 (2.35)	26.83 (3.42)
Mean LSAS scores	31.44 (13.77)	53.42 (22.69)
Mean age	29.36 (8.50)	27.25 (8.14)
Bias scores for Positive faces	0.92 ( $\sigma\bar{x}$ = 8.57)	13.36 ( $\sigma\bar{x}$ = 8.77)
Bias scores for Negative faces	-4.04 ( $\sigma\bar{x}$ = 9.12)	22.58 ( $\sigma\bar{x}$ = 9.34)

Bias score data was entered into a 2 x 2 repeated measures ANOVA with Expression Valence (Positive Expression vs Negative Expression) as the within-subject factor and Group (Low AQ vs High AQ) as the between-subjects factor. Total LSAS score was entered as a covariate.

Results from the analysis revealed a significant main effect of Group ( $F(1,46) = 4.32, p < .05$ ), showing the High AQ group had a greater bias towards emotional expressions regardless of valence compared to the Low AQ group. There were no significant main effect of Expression Valence ( $F(1,46) = .15, p > .05$ ) or interaction between Group and Expression Valence ( $F(1,46) = .52, p > .05$ , Figure 4.2).



*Figure 3.2.* Bias Score for Happy and Angry emotional expressions for Low and High ASC-trait groups.

To assess the attentional bias toward emotional expressions, mean Expression Valence bias scores for the Low AQ group (1.46) and the High AQ group (14.81) were independently subjected to a one samples *t*-test against a test value of 0 (no bias). This test reported that the Low AQ group did not show a significant bias for valenced emotional expressions ( $t(24) = 0.29, p > .05$ ), whereas the High AQ did show a significant bias towards valenced emotional expressions ( $t(23) = 2.33, p < .05$ ). This was also completed for each group for positively and negatively valenced expressions separately, showing no significant bias to a particular valence for either group (all  $p$ 's  $> .05$ ).

Finally, exploratory analysis looked at the five subscales of the AQ to determine if any of these had a driving effect on the result seen above. Each of the subscales underwent the same quartile split procedure detailed for the main analysis before being subjected to the same repeated measures ANOVA as the main analysis. This series of exploratory tests using a Bonferroni correction revealed that participants grouped into High and Low AQ groups based on the imagination subscale showed a difference in how they responded to emotional vs non-emotional faces. This result mirrored the result found in the main analysis, with High AQ group (i.e. those who had a poorer social imagination) showing greater attention towards emotional expressions ( $F(1,52) = 9.80, p < .01$ ). A follow up one-sample *t*-test against a test value of 0 revealed a significant attention bias for emotional

expressions in the High AQ group based on imagination subscale scores ( $t(27) = 3.12, p < .01$ ) that was not present for the Low AQ group ( $t(25) = -1.20, p > .05$ ).

## Discussion (4.9)

Results showed that individuals with a high number of ASC-traits were faster than those with fewer ASC-traits when responding to targets that appeared behind emotional faces compared to neutral faces. This finding reveals an attentional bias towards emotional expressions in people with a high degree of ASC-traits but without an ASC diagnosis. No differences were found between the groups for attention to positive versus negative valence expressions meaning no evidence was found for the specific valence of the faces affecting the allocation of attention in high trait individuals compared to those with fewer traits.

The current results are expected under the cognitive-motivational theory. The cognitive-motivational theory suggests that the salience for emotional expression information in people with high ASC-traits emerges from difficulties in real life understanding of the emotions and internal states of others. A lifetime of difficulty with emotional expressions would lead the Valence Evaluation System in high ASC-trait individuals to identify emotional expressions as important stimuli at an enhanced rate. This system would then drive allocation of attention towards these stimuli in order for the individual to enact self-preserving behaviour. This is similar to the salience for emotional expressions in clinical populations such as social anxiety, which is thought to arise from difficulty with such stimuli. The current findings are similar to results found from previous dot-probe studies which used clinical samples. Faster response times for probes that follow images relevant to a disorder have traditionally been interpreted as a greater attentional allocation for that stimulus (Bryant & Harvey, 1997; Mogg & Bradley, 1999; Watts, McKenna, Sharrock, & Trezise, 1986). It is suggested that this arises from a lifetime of difficulty with such stimuli.

Social difficulties are characteristic of ASC and include problems understanding the emotional and mental states of others. Social difficulties in ASC lead to problems in daily life which affect the maintenance of reciprocal relationships (DSM-V; APA, 2013).

Numerous empirical studies report that people with ASC have difficulty identifying emotional expressions (Ashwin, Chapman, et al., 2006; Braverman et al., 1989; Celani et al., 1999; Law Smith et al., 2010; Riby, Doherty-Sneddon, & Bruce, 2008), and research has also shown problems with emotion recognition are evident in the BAP (Bolte & Poustka, 2003; S. Smalley & Asarnow, 1990) and the WAS (Poljac et al., 2013). Deficits in attending and responding to the gaze of others has been shown in typically developing individuals in the BAP and individuals with a high number of ASC-traits (Chen & Yoon, 2011; Elsabbagh, Volein, Csibra, et al., 2009; Nummenmaa et al., 2011; Scheeren & Stauder, 2008). Research

such as this suggests that people with elevated ASC-traits have difficulty when trying to glean social information from the face and this could have led to increased attention under the cognitive motivation theory.

This interpretation of the results is supported from other methodologies that have been used to investigate abnormal attention for disorder related stimuli such as the modified stroop task (see above). With regards to ASC, research has shown that people with ASC show stroop interference effects to emotional faces compared to non-face objects (Ashwin, Wheelwright, et al., 2006). This suggests that ASC individuals may also have enhanced attention towards emotional faces which may arise due to repeated social difficulties in this condition. In sub-clinical participants from the general population, stroop research has found that higher ASC-traits are associated with greater attention to social words over non-social ones (Ashwin and Mansell, submitted), reinforcing the idea that attentional biases in non-diagnosed individuals with high ASC-traits may relate to real world difficulties. Therefore, the results seen for high ASC-trait individuals in the current study seem indicative of difficulties with emotional expressions in general and are supported by research from other domains and differing methodologies. However, one of the only studies that has explored attentional biases towards emotional expressions in ASC did not find results consistent with the current study, instead finding no attention bias for emotional expressions in children with ASC (Hollocks et al., 2013). Hollocks et al., used a participants group of children of various ages. As emotion processing ability develops throughout childhood, attention biases may have been obscured in this sample. Additionally, as the VES develops over repeated interaction and difficulty with external stimuli, a child sample may not have had the experience to acquire a lower attention threshold for attention stimuli at such an early point in development. Attentional biases for emotional expression information therefore needs to be tested in a sample of adults with ASC.

However, the results of the current study do not support the social motivation theory of ASC for those with high ASC-traits. If the social motivation theory was predictive of the behaviour of those with high ASC-traits, this group would be expected to have a diminished drive to attend to emotional expression stimuli. This also has implications for the results of chapter 3. In chapter 3, those with high ASC-traits were seen to have issues in identifying aftereffects arising from anti-angry expressions suggesting that the representational systems for emotional expressions could be under developed in this group. The social motivation theory would propose that this would occur due to a lack of experience with

emotion expression stimuli. However, the results of the current study suggest that those with high ASC-traits pay increased attention to emotion expressions. Any deficit in representing emotion expressions is unlikely to be due to a reduced drive to attend to such stimuli.

Interestingly, no effect was found for attention to negative emotional expressions over positive ones in those with a higher number of ASC-traits. Increased attention to negative emotional expressions may have been expected as in clinical ASC and those with high ASC-traits, negative expression recognition is especially impaired (Ashwin, Chapman, et al., 2006; Poljac et al., 2013). One reason that the current results may not have followed this trend could be that although impairments for negative emotion recognition in ASC are more prominent than those found for non-negative emotions the deficit is not specific and still affects all emotion based information (Blampied, Johnston, Miles, & Liberty, 2010; Rutherford & McIntosh, 2007). This interpretation suggests that ASC-like difficulties with emotion expression information would lead to increased salience for all emotional information, regardless of valence, owing to the difficulties encountered throughout life.

Additionally, the two groups used in this study differed on the levels of self-reported social anxiety with high ASC-trait individuals also having higher levels of social anxiety. Previous research presented here suggests that high levels of social anxiety lead to an attention bias for negative emotional expressions. However, this was not found in the current study which found no bias for any specific valence of emotion, but an overall bias for emotional expressions. This suggests that the reasons for increased attention for emotional expressions found in this study were not a merely an effect of social anxiety and instead reflected an effect of increased ASC-like traits.

It was not possible under the design of the current study to determine which aspects of the emotional face capture attention for those in the high ASC-trait group. The current study only assessed whether or not the emotional face as a whole captures attention. Previous research has shown that individuals with ASC pay more attention to the mouth region of the face (Klin et al., 2002), and especially avoid the eye region when making judgements regarding emotional displays (Boraston & Blakemore, 2007; Boraston, Corden, Miles, Skuse, & Blakemore, 2008). Other research suggests that when attention is directed towards the relevant facial features, people with ASC are better at making judgements on the emotional expression presented (López, Donnelly, Hadwin, & Leekam, 2004). If this is analogous to those with high ASC-traits in the WAS, it is possible that just one facial feature



in the images may have affected attention rather than the entire facial expression. By understanding whether there is a difference in which feature attracts attention between high and low ASC-trait individuals, we are able to ascertain whether those with high ASC-traits paid similar attention to all the information presented in the expressions in this study and the expression aftereffects in chapter 4.

The capture of attention by face parts in the WAS would need to be addressed separately. This could be done through using a dot-probe paradigm which employs face-parts (i.e. eyes and mouths) displaying emotional expressions or through conducting eye-tracking analysis of emotional faces for those with high ASC-traits. From this an understanding can be gained into whether attentional biases towards emotional expressions differ with regards to the information presented in different expressional facial features.

The current study did not allow for the assessment of different components of attention that are involved in the reported bias. For instance, although the bias suggests that people with high ASC-traits are biased towards emotional expressions, the current study did not assess the time course of attention. The current study used relatively long stimulus display timings as the literature has shown that individuals with ASC have been found to take longer to orient attention (Townsend et al., 1996) and it is uncertain whether this might extend to the WAS. Future research could employ faster stimulus display timings to test whether the bias towards emotional expressions in individuals with high ASC-traits persists at shorter stimulus durations. This would enable understanding as to whether those with high ASC-traits in the general population are similarly slow to shift, or disengage attention. Going forward this is a key question when considering the design of attention based studies in the WAS and the interpretation of results.

Finally, as the present sample was limited to a comparative group of people without ASC, who were typically developing but had high or low ASC-traits, it would be interesting to see whether further research could replicate the current findings in participants diagnosed with ASC. Not only would this allow for comparisons between the WAS to the behaviour seen in diagnosed autism, but under the spectrum approach to ASC, this could also help inform of the mechanisms for attention in ASC itself. This is especially crucial as a further test of the social motivation theory as this could help to build understanding as to whether this theory distinguishes between ASC and the WAS.

To conclude, the present results showed that those with a greater degree of ASC-traits showed an attention bias for faces with emotional versus neutral expressions, which was

not seen in those with a fewer ASC-traits. The attentional bias towards emotional versus neutral expressions in the high ASC-trait group suggests that emotional expressions have greater salience for this group which may emerge due to possible social difficulties in understanding the mental and emotional states of others. To fully appreciate the differences found across the spectrum of autism traits and how this result relates to diagnosed ASC and the social motivation theory of autism, further research investigating attention to emotional expressions is needed in samples of people diagnosed with ASC.

## **Chapter 5 – Study 3**

### **Using Eye tracking to explore the difference in attention to features of the emotional face across the autism spectrum**

Chapter 3 reported that those with high ASC-traits were less able to perceive an emotion aftereffect that typically appears negative in valence. This was suggested to mean that those with high ASC-traits may have an underdeveloped emotional expressions representation system. It was suggested that this could develop due to lack of experience with the social world resulting from a reduced drive to attend to emotional expressions. However, chapter 4 showed that those with high ASC-traits attend more to emotional expressions than those with fewer traits. To further test this, it is important to understand what feature of the face elicits attention. In addition, an alternative explanation to the chapter 3 results could be that those with a greater number of ASC-traits did not attend to the face in a typical way. If there are differences in the way that people with high ASC-traits attend to facial features, this could impact the information they were able to obtain from the briefly presented emotion aftereffects in chapter 3.

#### **Introduction (5.1)**

From birth, infants show preferential attention to human faces over other non-human and inanimate objects (Gliga et al., 2009; Morton & Johnson, 1991; Salva et al., 2011). This important behaviour could facilitate the perception of socially relevant information such as identity, facial expressions and speech. In general, studies have found that the eyes are the centre of focus when it comes to attending to faces (Janik, Wellens, Goldberg, & Dell'Osso, 1978). The eyes are a key area for perceiving social information and studies have shown that typically developed adults are able to infer an individual's mental state purely from the eye region of the face (Baron-Cohen et al., 1997). Further, eye tracking research has shown that attention towards specific facial features will vary as a function of the expression displayed on another individual's face, with negative expressions, such as anger, relying on the eyes (Eisenbarth & Alpers, 2011). This suggests that people's attention will be guided to the area with the most relevant, and salient information.

Research assessing social attention in ASC has shown that when people with ASC attend towards facial features, their pattern of attention varies from that of controls. A lack of attention for the eye region in ASC has also been shown with eye tracking research, with ASC individuals paying less attention to the eye region of the face than control participants when viewing images of faces (Chawarska & Shic, 2009; Kliemann, Dziobek, Hatri, Baudewig, & Heekeren, 2012; Kliemann, Dziobek, Hatri, Steimke, & Heekeren, 2010). Less attention for this region could lead to poorer ability when making judgments that involve the eyes. A study that highlighted this well showed that, when making judgments about displaced eye and mouth stimuli, ASC participants are impaired relative to controls on noticing displacements occurring in the eye region of the face but not the mouth region (Rutherford, Clements, & Sekuler, 2007). This result is suggested to arise due to limited attention to the eyes in ASC compared to unaffected individuals. Even when fixations towards the eye region have been found comparable to control participants, people with ASC still show aberrant scan paths for face stimuli which suggest that ASC individuals do not collate information from the face in the same way as controls (Rutherford & Towns, 2008; Trepagnier et al., 2002). This has been typified when people with ASC are told to attend to specific information displayed on the face, such as emotional expressions. Aberrant scan paths for faces in those with ASC exists regardless of whether or not the task instructions direct attention towards the emotional expression of the face stimuli (Pelphrey et al., 2002). Together, these findings suggests that facial attention exists in those with ASC, which mainly affect viewing of the eye region. This could potentially limit the social and emotional information ASC individuals can gather from faces.

The above research shows that when presented with specific facial emotional information, people with ASC tend to view the face differently than those without ASC. Further to this, research has shown that ASC participant's initial attention to the eye region of the face is moderated by the facial expression displayed. Kliemann et al., (2010, 2012) presented participants with fearful and happy expressions for 150ms. These expressions were presented at different positions on the screen in order to manipulate where participants starting fixation rested. Some trials presented faces with the eye region at initial fixation whereas other presented the mouth at starting fixation. Participants' eye movements were measured using eye-tracking technology and their first fixations were recorded. Kliemann et al., also recorded amygdala response during emotion expression presentation. Results showed that ASC participants made fewer fixations towards the eye region of the face and tended to look away from the eye region more than controls. In addition to this, Kliemann

reported that although overall fixations towards the eye region were lower in those with ASC, fixations were even lower when viewing fear expressions compared to happy expressions. What's more, those with ASC showed an abnormally increased amygdala response compared to controls when the starting fixation was in the eye region of the face. This could suggest that eyes are processed in a different way on a neural level in ASC. Heightened amygdala activation may be a sign of negative arousal (Le Doux, 1996) and uncomfortable feelings arising from this arousal could be one of the driving forces behind the avoidance of the eye region seen both in research and clinical descriptions of ASC (DSM-V; APA, 2013; Kanner, 1943). These results show that there are differences in the way that people with ASC attend to specific features of the face and that this could be moderated by the information presented on the face and driven by substrates such as the amygdala. Differences in fixation to facial features across distinct emotional expressions could be one of the effects driving the emotion recognition deficit seen in the condition.

One theory that attempts to explain this behaviour is the Social Motivational theory (Chevallier et al., 2012). This theory suggests that individuals with ASC have low social motivation driven by biological differences in substrates such as the amygdala and the reward system. Research presented above supports the presence of an aberrant profile of attention towards face features in ASC which has an underlying biological basis. What is less well understood, however, is whether this aberrant face processing style exists outside of the diagnosed condition of ASC and in those with high traits of ASC in the WAS and how social motivation theory extends to gaze behaviour seen in the WAS. Exploring this could help inform whether aberrant face gaze could be the reason for similar, yet milder difficulties with emotional expressions in such populations (Dawson et al., 2005; Johnson, 2005; Schultz, 2005) and will help to explore the results found in chapters 3 and 4.

Some evidence for general aberrant attention exists in relatives of those with ASC. One study assessing attention for faces in a cohort of unaffected siblings of ASC individuals and people with ASC and controls used eye-tracking and fMRI while participants observed faces (Dalton, Nacewicz, Alexander, & Davidson, 2007). The results showed that the ASC siblings gaze behaviour is similar to those with diagnosed ASC in that they spent less time looking at the eye region of the face compared with control participants. fMRI data showed decreased activation in the fusiform gyrus for the ASC siblings relative to control participants. This area of the brain is associated with face processing (Kanwisher et al., 1997). This research supports atypical gaze processing of faces that exists outside of those with a diagnosis and follows the predictions made by the social motivation theory.

As discussed in previous chapters, people from the general population have been found to vary on how they respond to social stimuli depending on the ASC-traits that they show. People at the high end of the WAS have been shown to attend to different aspects of the face. For example, Chen and Yoon (2010) investigated gaze behaviour in the WAS in response to direct gaze. Direct gaze, the act of making direct eye contact with another individual, is a strong social signal that implies that the target is the source of another person's attention. Chen and Yoon reported that those who have fewer ASC-traits tend to have longer fixation towards the eye region for direct gaze compared to people with higher ASC-traits, who did not show this same pattern. This mirrors results found in ASC, where gaze towards the eyes is reduced. The eye region could hold social information important to social interaction that is missed with reduced eye gaze behaviour. What isn't certain is whether attention to different regions of the face is modulated by the emotional expression displayed on the face similar to the avoidance of the eye region in response to negative emotional expression in those with ASC (Kleinhaus et al., 2010; 2012). If this is the case, this could be one reason for the profile of mild expression representation deficits seen at the high end of the WAS in chapter 3.

### **Aims and hypotheses (5.2)**

The aims of the current study were: (1) to test for differences in overall attention to facial features in high versus low ASC-trait groups, (2) to investigate differences between groups in initial attentional for specific facial features when they are initially fixating at the centre of the face and (3) whether this changes when expressions are presented to participants initially fixating on the eye or mouth region. (4) Additionally, the current study aimed to see if any differences in attentional patterns between groups vary depending on the emotional expression of the face.

Therefore it is hypothesized that in line with the social motivation theory that (1) Those with high ASC-traits will display reduced overall attention to face features of an emotional face than those with fewer traits of ASC. It is also hypothesized that (2) when presented with the centre of the face, the high ASC-trait group will implicitly shift attention less to the eye region and more to the mouth region of the face than those with fewer traits of ASC and (3) when presented with the eye region, the high ASC-trait group will not maintain attention at the eyes and instead look towards the mouth more than the low ASC group and when presented with the mouth region, the high ASC-trait group will not shift

attention away from the mouth region and towards the eye region to the same extent as the low ASC-trait group. Finally it is hypothesized that (4) the results will vary by emotion, with the high ASC-trait group showing less attention for the eye region of the face for negative versus positive or neutral emotional expressions in line with previous ASC research.

## Method (5.3)

### *Participants (5.3.1)*

Participants are outlined in detail in chapter 2. 39 total participants (28 female) took part in the gaze pattern analysis of the current study. 38 participants were used for first fixation analysis (27 female) as there was missing first fixation data for one participant.

Participants were divided into two groups through a median split procedure. This method created a Low AQ group with 19 participants ( $AQ \leq 16$ ) and a High AQ group with 20 participants ( $AQ \geq 17$ ). For the first fixation data there were 19 participants in each group using the same AQ threshold cut-offs.

Table 5.1

### *Demographic information and eye tracking data for high and low ASC-trait groups*

#### Demographics

And scores	Low AQ	High AQ	Sig
Mean AQ	10.95 (4.62)	22.05 (6.15)	$t=-7.63, p<.001$
Mean number of Fixations	92.26 (16.71)	98.35 (24.34)	$t=-.906, p>.05$
Mean Dwell Time	44.46 (1.68)	41.79 (1.29)	$t=1.27, p>.05$
Mean Number of First Fixations	22.52 (3.49)	23.16 (2.48)	$t=-.64, p>.05$

### *Stimuli (5.3.2)*

Images of 36 actors displaying happy, angry and neutral expressions were taken from the NimStim set of validated facial emotions (Tottenham et al., 2009). There were twelve examples of each of the three expressions. An equal ratio of male and female actors were used. The face stimuli were greyscale and mounted on a grey background.

The stimuli were not cropped into oval shapes as often done in eye-tracking studies because natural observation of faces was important for this study. Stimuli were presented as full face stimuli and occupied  $13^\circ$  of visual angle in width and  $17^\circ$  of visual angle in height



within the display. The face stimuli were presented on screen with either the eyes, nose or mouth of the model presented at the same position as the preceding fixation cross presented at the centre of the screen (herein referred to as the point of initial fixation; fig 5.1).



*Figure 5.1.* Examples of (a) a neutral expression with eyes presented at point of fixation (b) a happy expression with nose at the point of fixation and (c) an angry expression with the mouth at point of fixation.

Stimuli were displayed using Eprime psychological presentation software on a desktop PC running Windows 7 (Psychological Software Tools, CA). Data was recorded by a separate PC connected to an EyeTrac 6 Desk Mounted eye tracking device (Applied Science Labs, MA). The Eprime PC was connected to the eye tracking PC through a serial port. This setup allowed Eprime to control eye tracking PC recording behavior and register information such as trial number in a meaningful way.

As the analysis software cannot easily handle data presented in a different random order for each participant the presentation order of the trials in this study was initially randomized through the use of a random number generator. This means that each participant completed the study in the same order. No participant saw any stimuli more than once.

#### *Procedure (5.3.3)*

Eye tracking systems utilize ultraviolet light. Participants were therefore sat in a dimly lit room which occluded natural light. This helped to ensure that tracking was not interfered with by external sunlight. Participants were seated with their eyes approximately 57cm

away from the centre of the screen. This meant that the retinal image of the stimuli was consistent for each participant and that the size of the stimuli on the retina was controlled.

Participants underwent a calibration procedure using a 9-point calibration system. This was then checked for accuracy by asking them to look at each point again whilst the experimenter observed their fixations. Once calibration became accurate (no fixation more than 1° of visual angle away from the centre of each calibration point) the study began.

The study began by informing participants that they would see several faces displaying emotional expressions and instructing them to view these faces as naturally as possible, as if they were looking at someone in real life. Each trial began with a fixation cross presented at the centre of a grey screen for 3000 ms. The fixation cross was then removed and an emotional expression stimuli was presented. The face stimuli were presented with either the eyes, nose or mouth at the point of initial fixations (see fig 5.1). Participants had 5000 ms to view the face, after which time the face was removed from the screen and the fixation cross was presented signalling the beginning of the next trial.

#### *Analysis specifications (5.3.4)*

##### *Defining Regions of Interest (RoI) (5.3.4.1)*

Firstly Regions of Interest (RoI) were created in ASL results plus (Applied Science Labs, MA). There is not any one particular method as best practice. Some studies trace around specific features such as eyes, mouth and hairline, others use unequal RoIs that cover the features of interest and others still use equal sized RoI for each feature. For the current study RoIs were created that they were equal in size and covered the regions containing the eyes and mouths (fig 5.2). This allows for consistency within the results as it prevents a difference in fixation or gaze time being confounded by the raw area of the RoIs.



*Figure 5.2.* A screenshot from the analysis software showing ROIs over a stimulus used in the study.

#### *Defining Fixations and Dwell time (5.3.4.2)*

Fixations and dwells were measured in the current study. A fixation is defined as any point where an individual's gaze stops on a point on the screen for at least 70 ms (Duchowski, 2007; Salvucci & Goldberg, 2000). This is then recorded as a point of interest.

Dwell time, on the other hand, is continuous time based data. A single dwell is defined as the continuous amount of time that an individual spends with their gaze within a specific RoI before their gaze leaves that RoI. Dwell data is made up of many fixation points that occur continuously and sequentially within one RoI. Dwell data can be used to understand when a participant is spending time to examine an RoI.

The current study used 3 DV's:

- Total dwell time in an RoI
- Total number of fixations in an RoI
- RoI of first fixation following onset of the face stimuli

#### *Data Preparation (5.3.5)*

Data was initially exported on a trial by trial basis and manually arranged ready for analysis.

The current study created an average dwell and fixation value for each participant. The dwell value represented the average amount of time a participant spent dwelling in each region over the course of a single trial. The fixation value represented the average number of fixations participants made within each RoI

The first fixation data was collated for each initial fixation point condition separately (i.e. Initial fixation at eye, nose or mouth RoI for each emotion). A fixation was recorded as a first fixation if it occurred between 120 ms and 1000 ms of the beginning of the trial. The first fixation generally take around 120 ms to develop due to a delay between stimuli onset and first saccade (Purves, 2008). Any fixation prior to 120 ms is likely to be a resultant fixation based on the participant's attention to the fixation cross at the beginning of the slide. In addition to this, anything longer than a second may not be a first fixation, but a result of missed pupil or corneal reflection. It is methodologically and statistically safer to exclude these trials than to add potentially incorrect and noisy data to the analysis. Participants who had more than 50% of their first fixations >1000 ms were excluded from

the first fixation analysis (one participant). The RoI of the First fixation was tallied for each trial and data was then input into SPSS.

#### *Statistical procedure (5.3.6)*

Repeated measures ANOVAs were used to study both dwell time and number of fixations within both the eye and mouth RoIs. As there is interdependence between the eye and mouth regions (i.e. they are both displayed on the screen simultaneously) it would be statistically invalid to test against each other within the same statistical for any data that collects multiple responses per trial (i.e. average dwell time & number of fixations within an RoI). This data is, by its nature, highly negatively correlated. Therefore, four separate RM ANOVA were conducted on these data in order to avoid this issue:

- Average fixations within the eye region
- Average fixations within the mouth region
- Average dwell time in the eye region
- Average dwell time in the mouth region.

Conversely, for first fixation data only one item of data is recorded per trial. It is therefore appropriate to examine first fixations for eye region against those for the mouth region within the same ANOVA.

Emotional valence was included as a condition in all ANOVAs. This was done as it is important in order to investigate whether there are differences between high and low AQ groups in the number of fixations or average dwell time for facial features in general or whether differences arise for facial features depending on the expression displayed.

## Results (5.4)

### *Voluntary attention to facial features (5.4.1)*

To assess whether there were differences between the high and low ASC-trait groups in how they attended to the face across a whole trial, a 2 x 2 repeated measures ANOVA was conducted with Emotion (Happy vs Angry) as the within subjects variable and Group (High AQ vs Low AQ) as the between subjects variable. This analysis was conducted for both the total number of fixations within each ROI and average dwell time within each ROI.

#### *Fixations in the Eye ROI (5.4.1.1)*

Results for the number of fixations in the Eye ROI showed that there was no group difference for the number of fixations in this region ( $F(1,37) = 3.92, p=.055, ns$ ) nor was there a main effect of Emotion ( $F(1,37) = 1.51, p=.227, ns$ ). No interaction between Group and Emotion was found ( $F(1,37) = .499, p=.484, ns$ ).

#### *Fixations towards the Mouth Region (5.4.1.2)*

There were no group differences for number of fixations within the Mouth ROI ( $F(1,37) = .050, p=.824, ns$ ) nor was there a main effect of Emotion ( $F(1,37) = .01, p=.921, ns$ ). No interaction between Group and Emotion was found ( $F(1,37) = .84, p=.365, ns$ ).

#### *Dwell Time for the Eye Region (5.4.1.3)*

Results showed no group differences in how long people looked at one region before moving their attention to another region. Dwell time for the eye region did not differ by Group ( $F(1,37) = 1.61, p=.212, ns$ ) or Emotion ( $F(1,37) = 3.91, p>=.055, ns$ ). There was no interaction effect between Group and Expression Valence when assessing dwell time ( $F(1,37) = 1.37, p=.249, ns$ ).

#### *Dwell time for the Mouth Region (5.4.1.4)*

Similarly results confirmed no difference for how long participants dwelt on the Mouth ROI for Group ( $F(1,37) = 2.57, p=.117, ns$ ) or Emotion ( $F(1,37) = 1.69, p=.201, ns$ ). No interaction between Group and Emotion was found ( $F(1,37) = .010, p=.921, ns$ ).

#### *Ratio of fixations between eyes and mouths (5.4.1.5)*

To investigate how the ratios of attending towards the eyes versus mouths might differ between groups, a bias score was created. In this context a bias score represents the ratio of fixations between the eye and mouth ROIs. The ratio was computed by taking each

participants average number of fixations to the eye region and dividing it by the sum of fixations of both the eye and mouth region combined:

$$\frac{\text{Fixations in the Eye RoI}}{\text{Fixations in the Eye RoI} + \text{Fixations in the Mouth RoI}}$$

This gives each participant a bias score indicating the interest they had in the eye region relative to the mouth. A one way ANOVA showed that there was no difference between those with high and low autism traits in the amount of fixations they had at the eye region relative to the mouth region ( $F(1,37) = 1.508, p=.227, ns$ ).

#### *Initial attention for facial features (5.4.2)*

##### *First Fixation Data (5.4.2.1)*

Eyetracking studies produce a lot of data. This can be simplified by reducing some of the data down through creating bias scores from multiple variables. In the current study, for example, a bias score can be created between the number of fixations that occur in the eye and mouth region. This is useful as it allows insight into how participants were attending to one area in relation to another area, however the raw number of fixations to a single region of interest is lost when performing calculations with bias score and this data can hold some useful information.

Therefore the analysis of group differences in fixations to each region will first be explored. Following this an aggregate bias score will be created and used in order to assess interactions between the remaining variables.

##### *First Fixations to the eye region*

When collapsing across emotion and initial fixation position, no overall differences in fixations to the eye region arose ( $t(36) = 1.629, p=.112$ ). When collapsing across initial fixation position, no differences were found for fixations to the eye for Happy ( $t(36) = 1.023, p=.313$ ) or Angry ( $t(36) = .146, p=.885$ ) expressions. When collapsing across emotion, there were no differences for fixations to the eye region regardless of the participants' initial fixation (all  $p$ 's  $>.05$ ). The only group difference that arose was for fixations to the

eye region for happy expressions when fixation was at the centre of the face ( $t(36) = 2.105$ ,  $p=.042$ ), where the High AQ group had fewer fixations to the eye region.

#### *First Fixations to the mouth region*

When collapsing across emotion and initial fixation position, no overall differences in fixations to the mouth region arose ( $t(36) = -1.025$ ,  $p=.312$ ). This did not change when collapsing across initial fixation position to examine expressions of Happy ( $t(36) = -.747$ ,  $p=.460$ ) and Angry ( $t(36) = -1.115$ ,  $p=.272$ ) separately. When collapsing across emotion, for initial fixations at the centre of the face and at the eye region, the groups showed no differences across emotion ( $p's > .05$ ). However, the High AQ group showed significantly more fixations at the Mouth region when the initial fixation was at the mouth ( $t(36) = -2.427$ ,  $p=.020$ ). When broken down by emotion, this effect was driven by increased fixations to the mouth region for Angry expressions in the High AQ group ( $t(36) = -2.633$ ,  $p=.012$ ).

#### *Within Group First Fixations to Eye and Mouth Regions*

When initial fixation was at the centre of the face, the Low AQ group showed a preference for attending to the Eye region regardless of expression ( $t(18) = 2.234$ ,  $p=.038$ ). The high AQ group did not show this pattern ( $t(18) = -.212$ ,  $p=.835$ ). The Low AQ group showed increased fixations to the Eye region compared to the Mouth for Happy expressions ( $t(18) = 2.550$ ,  $p=.020$ ) which was not observed in the High AQ group ( $t(18) = -.348$ ,  $p=.732$ ). Contrary to this, for expressions of Anger, the Low AQ group did not show any increase in fixations to the Eye over the Mouth region ( $t(18) = 1.163$ ,  $p=.260$ ), but the High AQ group showed a significantly higher number of first fixations to the Eye region compared to the Mouth ( $t(18) = 2.126$ ,  $p=.048$ ).

#### *First fixations away from the point of initial fixation*

In order to also see whether participants moved their fixation away from the points that the study initially fixated them on, an analysis that looked at all fixations occurring outside of the point of initial fixation region was conducted. This analysis was conducted only for trials where fixations were initially set on the Eye and Mouth region. This analysis can help determine whether participants differed on whether they were able to move their attention to different regions successfully, or whether their attention got stuck at the initial feature they were presented with.



A 2x2x2 RM ANOVA with Emotion (Happy vs Angry) and Initial Fixation Position (Initial fixation Eye vs Initial Fixation Mouth) as the within subjects factors and Group (High AQ vs Low AQ) as the between subjects factors was conducted on first fixation data for trials that presented either the Eye or Mouth region at the point of initial fixation. The data used for this ANOVA was the number of first fixations that did not remain in the point of initial fixation (i.e. fixations away from the Eye RoI or fixations away from the Mouth RoI). The results revealed a main effect of Initial fixation ( $F(1,36) = 9.76, p < .01$ ), showing that forcing initial fixations to the mouth resulted in more first fixations away from the point of initial fixation. An interaction of Emotion and Initial fixation point was found ( $F(1,36) = 16.55, p < .001$ ), showing that participants moved their fixations away from the eyes more for Angry expressions. Finally, an interaction between Group and Initial fixation ( $F(1,36) = 4.79, p < .05$ ) showed that the Low AQ group were more likely than the High AQ group to move their first fixation away from the Initial Fixation Point when the Mouth was presented at the point of initial fixation. An independent samples *t*-test confirmed that this was driven by the Low AQ groups drive move their first fixation away from the Mouth RoI ( $t(36) = 2.60, p < .05$ ).

#### *Analysis of bias to the eye region*

In order to test ratio of first fixations to eye and mouth regions, a 2x3x2 RM ANOVA was conducted on bias score for the Eye RoI for each participant, Emotion (Happy vs Angry), Initial Fixation Feature (Initial Fixation Eye vs Initial Fixation Mouth vs Initial Fixation Centre), and Group (High AQ vs Low AQ) as the factors. This analysis revealed a significant 3-way interaction between Group, Emotion and Initial fixation point ( $F(2,35) = 4.967, p = .013$ ). Further ANOVAs were then conducted to identify the nature of this interaction. The data was broken down by Initial Fixation point and 2x2 RM ANOVAs were conducted for each of the three levels of initial fixation. This led to a separate ANOVA for stimuli presented with the initial fixation at the Eyes, Mouth and Centre of Face.

#### *Initial Fixation at the Centre of the face (5.4.2.2)*

A 2x2 RM ANOVA with Emotion (Happy vs Angry) as within subjects factors and Group (High AQ vs Low AQ) as between subjects factors was conducted on all first fixation data that was recorded when the initial point of fixation was at the centre of the face. This analysis revealed a significant interaction between Emotion and Group ( $F(1,36) = 11.35,$

$p=.002$ ). This interaction showed that the high group had a lower bias for attending to the eyes than the low AQ group for Happy expressions ( $t(36) = 2.50, p=.017$ ) but not for Angry Expressions ( $t(36) = .915, p=.366$ ).

*Figure 5.3 – graph of biases when fixation at centre of face*

#### *Initial Fixation at the Mouth region (5.4.2.3)*

A RM ANOVA with Emotion (Happy vs Angry) as the between subjects factors and Group (High AQ vs Low AQ) as the between subjects factor was conducted on all first fixation data that was recorded when the initial point of fixation was at Mouth region of the face. There was no Interaction or main effect for Group or Emotion (all  $p's > .05$ ).

#### *Initial Fixation at the Eye region (5.4.2.4)*

A Final RM ANOVA with Emotion (Happy vs Angry) as the within subjects factor and Group (High AQ vs Low AQ) as the between subjects factor was conducted on all first fixation data that was recorded when the initial point of fixation was at Eye region of the face. No main effects or interactions arose from this analysis (all  $p's > .05$ )

## Discussion (5.5)

The current study aimed to use eye tracking to explore whether there is a difference in the way people with high levels of ASC-traits scan emotional expression faces compared to those with fewer traits. The current study found no differences between groups in overall face scanning as measured by overall number of fixations towards the eyes and mouths of expressional faces, and the amount of time each feature was viewed. However, group differences arose when assessing the first fixations of individuals with high and low ASC-traits. First fixation analysis revealed that people with low ASC-traits but not high ASC-traits directed their attention from the middle of the face to the eye region for happy expressions. Importantly, the bias for attending to the eye region was lower in people with more ASC-traits than those with fewer traits for happy expressions.

Additionally, for angry expressions, high ASC-trait individuals had more fixations to the mouth region. When participants were presented with the eyes or mouth at fixation, the low ASC-trait group consistently attended to the eye region, even when this meant moving attention away from the mouth. However, the high ASC-trait group were less likely to move their initial attention from which ever feature (eyes or mouth) they had been presented with at the point of fixation. This has implications for the current thesis, and for the study of facial expression processing in the autism spectrum more generally.

The current study is the first to show differences in first fixations towards facial emotional expressions in those with high and low levels of ASC-traits. This research is similar to research in the ASC literature that shows that individuals with a clinical diagnosis of ASC tend to have aberrant face gaze patterns (Bal et al., 2010; Boraston & Blakemore, 2007; Klin et al., 2002; Pelphrey et al., 2002; Snow et al., 2011). This work supports the spectrum view of autism, as those with higher than average levels of ASC-traits tend to show differences in this area, in a similar way to those with a diagnosis. However, when assessing individuals with ASC, they generally seem to have an overall difference in the way they view faces rather than being confined to first fixation difference. For example, Pelphrey et al., (2002) showed that those with ASC had fewer fixations to the core features of the face, such as the eyes as well as an atypical scanning pattern. Scan path analysis was not conducted in the current study, but high and low ASC-trait individuals were not found to have a different number of fixations or dwell time for the eye and mouth regions of the face. This does not support a difference in viewing patterns between the two groups. However, a difference in the initial fixation to different facial features between these groups was found. This result suggests that the difference between ASC and people with

high ASC-traits may relate to the development of ASC as predicted by the social motivational theory. The social motivational theory suggests that initial problems with attention to social stimuli might lead to later behavioural and cognitive atypicalities. For example, Pelphrey et al.'s result of aberrant face scanning could be interpreted as atypicalities with initial attention mechanisms which prevent learning face scanning in a typical way. The current results show that people with high ASC-traits show differences with initial orientation to social stimuli such as face features, but there is no evidence that they show differences in overall levels of attention to the eye and mouth regions as would be expected by the social motivation theory. Future research investigating differences between initial orienting and disengagement issues and overall scan paths may shed light on the difference between those with high ASC-traits and those with a diagnosis and could be important for possible avenues for intervention.

The current study showed a difference in first fixation behaviour when a face was presented with the point of fixation in the middle of the face (nose). At the middle of the face there is generally less social information so participants therefore generally shift their attention to a socially relevant area of the face (Janik et al., 1978). Participants with high traits of ASC attended to the eye region of happy expression comparatively less than those with fewer ASC-traits in the current study. This would be predicted under the social motivational theory of ASC and mirrors previous ASC research. However, this result was only apparent for happy expressions and did not occur for angry expressions or when collapsed across emotion. This is difficult for the social motivational theory to explain.

Previous research in ASC generally shows that the eye region is attended to less than the mouth region. Even in the BAP, siblings of those with ASC tend to have a similar gaze pattern to that seen in ASC (Dalton et al., 2007) and research studying people without ASC but with high ASC-traits found that high ASC-trait individual looked at the eye region of the face less than low ASC-trait individuals when the eyes were showing direct gaze (Chen & Yoon, 2011). Based on the social motivational theory, the current study therefore hypothesised that high ASC-trait individuals would look less at the eye region of emotional faces. This result was partially confirmed but only for happy emotional expressions. The current study found that attention to facial features in high ASC-trait individuals was moderated by the emotion displayed on the face. This result is interesting as it hints at atypical attention to faces in ASC that does not correspond completely with previous results found in diagnosed ASC or the BAP and is not what would be expected by the social motivation theory.

An alternative explanation of the difference in first fixation between positive and negative emotional expressions may be that the results relate to the salience of the emotional expression context that the face the features appear in. According to the cognitive-motivational perspective (Mogg & Bradley, 1998), each individual has an attention threshold for stimuli that signify threat. A threat stimuli could be anything that causes an individual difficulty. Once there is an external stimulus in the environment that crosses an individual's threat threshold, a cognitive mechanism, the VES will draw attention to that stimulus. However, when an individual has difficulty with a certain stimuli, their threat threshold for that stimuli decreases due to the repeated negative state it caused them. In this case, their VES will draw attention to threat at lower levels than those who have not had the same negative experiences. This signifies that the stimuli is important to attend to. As discussed in previous chapters, people with ASC and those with high self-reported traits of ASC have specific difficulties with emotional expressions throughout life. Emotional expressions, particularly negative emotional expressions, are known to cause difficulty for these individuals. The eye region of the face is generally more expressive of an individual's emotional and underlying mental state (Baron-Cohen et al., 1997; Janik et al., 1978) and people with ASC and high ASC-traits generally have trouble identifying mental states from the eyes. Therefore, although the finding that people who have high traits of ASC look more towards the eye region than the mouth region of a face displaying a negative emotion would not be expected under a social motivational approach, this would be expected under the cognitive-motivational perspective. This arises because angry expressions may be more likely to activate the flight of fight defence systems of those with high ASC-traits due to a lowered VES threshold and so their attention mechanisms direct their gaze towards the most salient feature of the threat, namely the eyes in the angry face. This result and its interpretation generally supports the results found in Chapter 4, where individuals with high traits of autism paid preferential attention to emotional faces over non-emotional ones.

However, the current study didn't find increased attention for any facial region of happy expressions for those with high ASC-traits. This would also be needed to fully support the cognitive-motivational perspective and the results found in chapter 4. This could be because those with ASC and high ASC-traits do not have as great a difficulty with positive expressions as they do negative ones (Ashwin, Chapman, et al., 2006; Law Smith et al., 2010). The high ASC-trait group did not show the same initial attentional for the eyes of a happy expression over the mouth region as the low ASC-trait group. The cognitive-

motivational perspective can account for this behaviour. The difference between attention capture by facial features of happy and angry expressions for high ASC-trait individuals could be explained by happy expression not achieving the same threat level as negative ones by individuals with high ASC-traits. This explanation is possible as people with ASC and those with High ASC-traits do not show the same level of difficulty with positive emotional expression recognition as they do with negative emotion expression recognition. Further to this, the likelihood and consequences of misinterpreting positive emotional expressions are not as severe as the consequences of misinterpreting negative emotional expression information.

However, previous studies using a similar design to assess fixations to eye and mouth regions in those diagnosed with ASC have shown decreased fixations towards the eye region for negative emotional expressions (Kleimann et al., 2010; 2012). This is inconsistent with the findings from the present study. These results suggest that the cognitive motivational approach, may explain aberrant attention to faces at the high end of the WAS, but not in those diagnosed with ASC, suggesting different mechanisms exist between these two groups for face processing.

The results of the current study also help to interpret the results of chapter 3. Those with high ASC-traits have an aberrant first fixation pattern for emotional faces. This could therefore mean that the high ASC-trait group who showed reduced perception of the negative aftereffect produced by adaption was in fact just using a different attentional strategy to perceive the face and emotional expression aftereffect. However, this is unlikely to be the case, as the high ASC-trait individuals in this study looked towards the eye region of negative faces more than low ASC-trait individuals. This suggests that the results of chapter 3 cannot be explained by high ASC-trait individuals looking at the incorrect aspect of the emotional aftereffect. This suggests that the deficits seen in chapter 3 were likely due to mild impairments with the emotion expression representations.

A second interesting result that arose from the current study is that people with high ASC-traits tend to get their attention 'stuck' on the feature they are initially presented with. In the current study, both groups' attention remained at the eye region of the face when the eye region was presented as the point of initial fixation. However, when the mouth was presented at the point of initial fixation low ASC-trait individuals shifted their attention away from the mouth, whereas high ASC-trait individuals were more likely to remain attending towards the mouth. Previous research from ASC and the BAP has shown that

these individuals have difficulty disengaging their attention when presented with two or more competing stimuli. For example, Elsabbagh, Volein, Holmboe, et al. (2009) used the Gap-Overlap task with infant siblings of ASC children at 10 months. The Gap-Overlap task consists of two conditions which presents children with a central fixation prior to presenting two peripheral targets. On “gap” trials the central fixation is removed prior to the presentation of the peripheral stimuli. On “overlap” trials the central fixation remains on screen as the two peripheral stimuli appear. These are measured against a baseline condition where the central fixation is removed at the point at which the peripheral stimuli appear. A gap prior to the presentation of peripheral stimuli is thought to facilitate attentional orienting, whereas the presence of an overlap is thought to tap disengagement mechanisms as the infant has to explicitly move their attention. Elsabbagh et al., (2009) found that infant siblings of ASC individuals tended to have delayed disengagement from the central fixation, suggesting that attention deficits exist outside of those diagnosed with ASC. In line with the results of the current work, Elsabbagh suggested that social deficits seen across the spectrum of autism may arise from inappropriate disengagement in day-to-day life. If an individual over fixates on a stimuli they may miss important aspects of the environment that hold valuable social information. However, Elsabbagh et al., (2009) assessed attention deficits using non-social stimuli. There is less research assessing differences in attention to social stimuli and the current work helps to expand and support Elsabbagh’s (2009) interpretation. The results here are likely highlighting that those with high ASC-traits also have issues when disengaging attention, but this study has highlighted this with regards to social face stimuli. This could help understanding as to why there are mild emotional expression difficulties seen in the WAS. If high ASC-trait individuals have trouble disengaging from the region of the face they are currently viewing, they could potentially miss valuable social information presented elsewhere on the face. This interpretation supports the social motivational theory as it could be that mild impairments with brain substrates linked to social attention, such as the amygdala, in high ASC-trait individuals may be impaired. This could have also led to reduced experience with emotional expressions and face stimuli in these individuals, which would lead to an underdeveloped face-space and help explain the results of chapter 3. This would have to be explored in a paradigm that measured amygdala and other social brain activity in a similar task as the current study which is outside of the scope of the current work.

There are some limitations to the current study. Unfortunately, a large amount of participant data was removed from this study owing to technical issues and therefore could

have led to the no-effects seen in the overall fixation and duration data. This could therefore mean that some of the results found during the analysis did not reach significance because of the limited power left in the study at this stage. This is an unfortunate side effect of exploring behaviour using eye tracking. In future, this could be accounted for when running the power analysis. Based on the attrition experienced in the current study, it would be necessary to recruit around double the necessary number of participants to account for this technical attrition.

Further to this, the current study used only one type of negative expression: anger. Anger was used in the current study as it was used in previous chapters and its inclusion here could help to interpret those results found previously. Previous research in ASC has used different expressions (fear) and there may be limits to how far the results can be compared to other studies. Repeating the study with both high ASC-trait individuals and those with ASC, but using many different negative emotional expressions could help to develop a complete picture of how the difficulties seen in high ASC-trait individuals relate to ASC and previous research in the field.

Another issue with the stimuli is that some displayed teeth and others did not. The teeth add a high level of contrast to the image. This was necessary as the aim of the study was to observe face gaze in as natural way as possible. Additionally, the teeth are an aspect of emotional expressions and it is important to use stimuli that include them. However, a control task that simulates this should be used in future to assure that this isn't confounding by drawing attention to this area for non-social reasons. This is unlikely, however, as stimuli across all conditions displayed teeth and this could have acted to control for this effect.

In closing, the current study did not find difference how people with high and low levels of ASC-traits choose to split their time when look at the features on emotional faces. However, these two groups showed a different pattern of first fixations which hints at differences in initial attention across the WAS. This differences was observed both when looking at orientations towards and away from crucial face features. Furthermore, these differences were not apparent for face stimuli in general, but differences were related to specific emotional expressions. The results presented here suggest that although the social motivational approach to ASC can explain some aspects of face gaze behaviour in high ASC-trait individuals, there is a distinction between those with high ASC-traits and diagnosed ASC in this area. Furthermore, for initial orienting behaviour, the cognitive motivational



account of attention provides a better account of the initial face orienting behaviour differences seen at the high end of the WAS.

# **Chapter 6 – Study 4 –**

## **Testing the recognition of mild facial expression in those with high and low ASC-traits.**

### **Introduction (6.1)**

The results of study 1 showed that those with high ASC-traits had reduced aftereffects for stimuli which normally produce negative aftereffects. These results show that people with high ASC-traits may have mild difficulties creating representations of negative emotional expressions. In addition to this, the results of chapter 4 and 5 showed that people with high ASC-traits were more likely to attend to emotional expressions and to the eye-region of angry expressions over the mouth region. According to the cognitive motivation theory, these attention biases could arise due to difficulty with these stimuli. If people with high ASC-traits do have difficulty with expression information arising from inefficient representational systems, this can be probed by assessing recognition of subtle difficulties.

The ability to process emotional expressions of the face has been well researched with regards to ASC as explored in previous chapters. Although this research is mixed, meta-analyses show that a difficulty in recognising emotional expressions is a robust finding in ASC, even after correcting for publication bias (Uljarevic & Hamilton, 2013). However, this issue has been explored to a much poorer extent in the BAP and the WAS.

Research investigating emotion recognition in the WAS has reported that those with higher ASC-traits require more information in order to identify emotional expressions. Poljac et al. (2013) gave participants an emotion recognition task using morphed expression videos that developed from neutral into a full-blown expression. The high ASC-trait group identified the expression at a further point in the scene, when the expression had developed to a further and more extreme point. Even then, accuracy was still poorer for the high ASC-trait group compared to the low ASC-trait group for the negative expressions of sadness, anger and disgust. This task highlighted that those with higher ASC-traits needed to see the emotional expressions longer in order to correctly identify the emotional expression. This effect was especially evident for negative emotional expressions, consistent with previous research in ASC showing difficulties in emotion processing specific to negative valence (Ashwin, Chapman, et al., 2006; Law Smith et al., 2010). Although it's possible that the high

ASC-trait group needed more information in order to identify the emotional expression presented in the video scenes, they may have instead just required longer to respond to the emotional expression. Poljak et al., cannot distinguish between these two explanations.

Evidence from Nixima, Fujimori, and Okanoya (2013) goes some way to disentangle this effect. Participants were presented images of people expressing emotions with three levels of emotional expression intensity (low, medium and high) for three different emotional expressions (happy, angry and neutral). Images of the expressions were presented for 500 ms. This study found no difference in accuracy between those with high, medium or low ASC-traits when identifying emotional expressions of different intensities, those with high traits took longer to respond. This suggests that those with high ASC-traits may need more time to successfully label emotional expressions rather than needing more expressional information as suggested in Poljak et al., (2012). However, the study by Nixima et al., involved a non-validated emotional expression set. Therefore, the lack of group differences may be attributable to discrepancies in the stimuli used as it is uncertain that the expression were representative of different strengths of emotional expressions. Another issue is that the study only used angry, happy and neutral expressions. When participants have such a limited number of emotions to choose from in a forced choice paradigm, “best guesses” are likely to be more accurate as there are fewer similar, but incorrect answers to choose from for each expression. Further, this is an issue when aiming to conduct useful error analysis as there is less diversity of information. Error analysis, the process of examining the kinds of errors individuals make when they make incorrect judgements, can help researchers understand why such errors occur. By offering participants a wider selection of emotional expression labels from which to choose from when judging emotional expressions, error analysis becomes possible and informative.

One study that explored emotion recognition in the BAP included a validated stimuli set along with a greater number of different emotion expression examples. When assessing a group of parents of individuals with ASC compared to a matched control group, Neves et al. (2011) reported that parents of people with ASC got more mild emotional expressions incorrect than control participants. What’s more, when this group did make an incorrect choice, they often labelled the mild expression as a neutral face, suggesting that they may not be processing this information in a way that allows them to appreciate the mild valence. In addition they found the parents of ASC individuals were slower at making their responses to emotional expression stimuli than the control group. The design of this study allowed participants to view the stimuli without time restriction and only moderated the

intensity (low or high) and the type of expression (fear, anger, sad, happy and no expression). Results showed the expression strength of the stimuli produced differences in accuracy between groups. In addition results showed a longer amount of time was needed by those with high ASC-traits, showing the importance of time limitations in emotion recognition in the autism spectrum. However, although BAP participants took longer to respond, all participants were given unlimited viewing time. It is therefore uncertain what drove the reaction time differences in Neves et al. For example, BAP participants may have spent more time viewing the face which would have increased reaction time or alternatively they may have used a different, compensatory mechanism in order to identify the face, which may lead to greater reaction time. Limiting viewing time could help to uncover the cognitive mechanisms underlying the reported reaction time differences. Additionally, this study involved people with the BAP, so it is currently unknown if people who have high traits of ASC would show the same pattern of results.

It is important to understand how those with high and low traits of ASC are able to recognise emotional expressions. This is particularly pertinent to the results of chapter 3. Chapter 3 reported that when identifying the adaptation aftereffect that should appear negative, those with high ASC-traits performed no better than chance. This could be because they have difficulty representing this information on a neural level, which could lead to trouble identifying subtle representations of expressions. Adaptation aftereffects are, by their illusory nature, subtle representations. If those with high ASC-traits have difficulty interpreting subtle (and in particular, negative) emotional expressions this has implications for the interpretation of these previous results.

Previous research suggests that there are difficulties in processing mild emotional expressions in ASC and that it might also be an issue for people in the BAP and WAS, although results have been mixed in this latter group. The current study investigated mild emotion recognition ability in people high and low in ASC-traits while addressing some of the potential limitations in previous studies. For these reasons the current study uses a wider range of emotions, a restricted stimuli presentation time and a validated emotion expression set to explore mild emotion expression recognition in those with high vs low traits of ASC.

### **Aims and hypotheses (6.2)**

The aims of the current study were to: (1) to test for general differences in recognising high versus low intensity emotion expressions, (2) to investigate differences between high and

low ASC-trait groups in recognising emotions of low and high intensity, (3) whether any differences in recognising high and low intensity emotions might vary depending on the emotion expression, (4) to investigate differences in response times between high and low ASC-trait groups when judging emotions of low and high intensity , and (5) whether high and low ASC-trait groups incorrectly perceived mild expressions as not having valence.

It was expected that (1) low intensity emotions will be perceived less accurately than high intensity emotions, (2) the high ASC-trait group will be less accurate than the low ASC-group when identifying mild emotional expressions, (3) high ASC-trait group will be less accurate than the low ASC-trait group in identifying negative expressions, (4) the high ASC-trait group will take longer than the low ASC-trait group to respond to negative emotional expressions and (5) the high ASC-trait group will perceive more mild expressions as neutral than the low ASC-trait group.

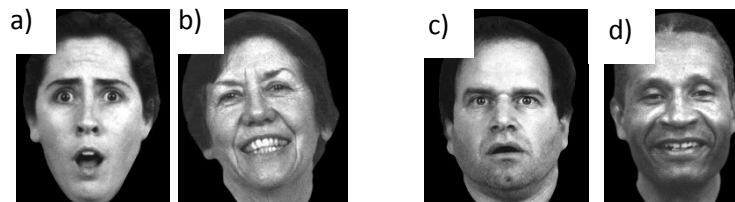
## Method (6.3)

### *Participants (6.3.1)*

105 participants (52 female) with a median age group of 18-25 took part in the current study. This sample is different to those recruited in previous studies. Participants were split into a low ASC-trait group with 23 participants (8 female,  $AQ \leq 13$ ) and a high ASC-trait group with 26 participants (10 female,  $AQ \geq 23$ ).

### *Stimuli (6.3.2)*

All 40 images from the Penn Emotion Recognition Test 40 (ER40; Gur et al., 2001) were employed in the current study. The ER40 facial emotion expression set displays actors of different ages, genders and ethnicities displaying both mild and extreme emotional expressions. The faces displayed expressions depicting happy, sad, anger, fear and neutral (i.e. no emotion). There are 8 images for each of the emotional expressions, four of which are mild depictions and four are extreme depictions. There are 8 depictions of neutral which, of course, do not vary in intensity (fig. 6.1).



*Figure 6.1.* Examples of (a) extreme fear (b) extreme happy (c) subtle fear and (d) subtle happy.

These stimuli have been previously been used to investigate individuals with ASC (Sasson, Pinkham, Faso, Simpson, & Kelsven, 2014), and has been used to assess emotion processing in the relatives of autism (Neves et al., 2011). The test has previously been used to identify differences in the way that clinical populations identify subtle emotional expressions (Eack et al., 2009; Gold et al., 2012; Kohler, Barrett, Gur, Turetsky, & Moberg, 2007) and in populations of individuals who are at risk of developing clinical disorders (Eack et al., 2009).

### *Procedure (6.3.3)*

The study was completed outside of the lab environment on a Toshiba Laptop running Eprime. For each participant a quiet place in their current environment (home or office) was located in which to conduct the study and which was chosen to be as consistent as possible across all participants. Participants were initially briefed about the task. Informed consent was obtained from each participant.

#### *ER40 procedure (6.3.3.1)*

The emotion expression recognition task was set up to display each face from the collection in a random order. Each trial began with a fixation cross in the centre of the screen for 500 ms followed by the presentation of a face for 300 ms. This presentation time was used in order to match the conditions in the adaptation task in chapter 3. Once the face expression stimuli had been briefly displayed, numbered response options were presented on screen. The response options ranged from 1-5 and the emotion expression included here were Neutral, Fear, Anger, Happiness and Sadness. Participants were required to use the number pad on the keyboard to make their responses.

Participants had 10000 ms in which to make their judgements. After a judgement had been recorded (or after the maximum time allowance), the trial ended and the next trial began following a 500 ms ITI. There were 40 trials in total, and following completion of these trials participants were thanked for their time and debriefed as to the aims of the study.

## Results (6.4)

An independent-samples *t*-test revealed that the high and low ASC-trait groups did not differ on age ( $t(47) = 1.06, p > .05$ ), and a chi-square test revealed no differences between groups for sex-ratio ( $\chi^2(1, N = 49) = .790, p > .05$ ). The two groups were assessed for the existence of a speed vs accuracy trade off between overall accuracy and overall reaction time on the ER40. Results showed no evidence of a speed vs accuracy trade off in the High ( $r = -.131, n = 26, p > .05$ ;) or Low ( $r = -.068, n = 24, p > .05$ ;) AQ Groups.

### *Emotion Recognition*

#### *Accuracy Data (6.4.1)*

The accuracy data was entered into a 4 x 2 x 2 repeated measures ANOVA with Emotion (Happy vs Anger vs Fear vs Sadness) and Representation (Mild vs Extreme) as the within factors and Group (High AQ vs Low AQ) as the between subjects factors. Neutral faces were analysed separately as they did not have both a mild and an extreme representation.

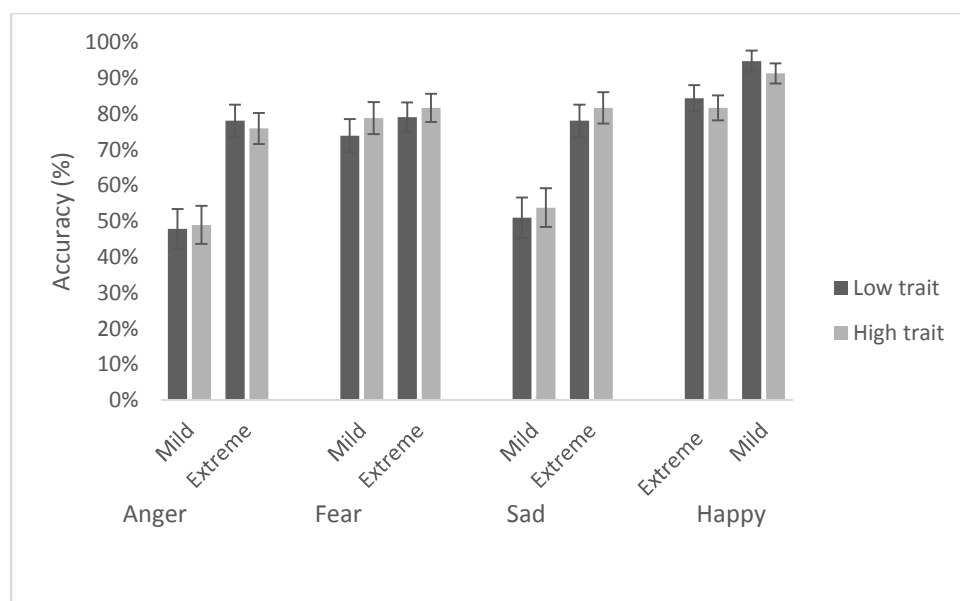
The analysis found a significant main effect of Representation ( $F(1,47) = 78.08, p < .001$ ), which revealed that participants identified strong representations of emotions more accurately than they identified mild representations of emotion. There was also a main effect of Emotion ( $F(3,144) = 23.23, p < .001$ ). Post-hoc tests showed that following a Bonferroni correction, Happy emotions were perceived significantly more accurately than all other emotional expressions and that Fear was perceived significantly more accurately than Sad and Anger expressions (all  $p$ 's  $> .05$ ). There was no main effect of Group ( $F(1,47) = .07, p > .05$ ).

An interaction between Representation and Emotion was found. Post-hoc paired samples *t*-tests showed that for Happy, Angry and Sad expressions, Extreme representations were recognised better than Mild representations. There was no difference in accuracy scores between Extreme and Mild representations for Fearful faces.

The interactions between group and representation ( $F(1,47) = .125, p > .05$ ), Group and Emotion ( $F(3,144) = .51, p > .05$ ) and Group, Representation and Emotion ( $F(3,141) = .06, p > .05$ ) did not reach significance (fig 6.2).



*Figure 6.2.* Bar chart highlighting the differences accuracy scores for mild and extreme representations of the emotional faces used in the current study.



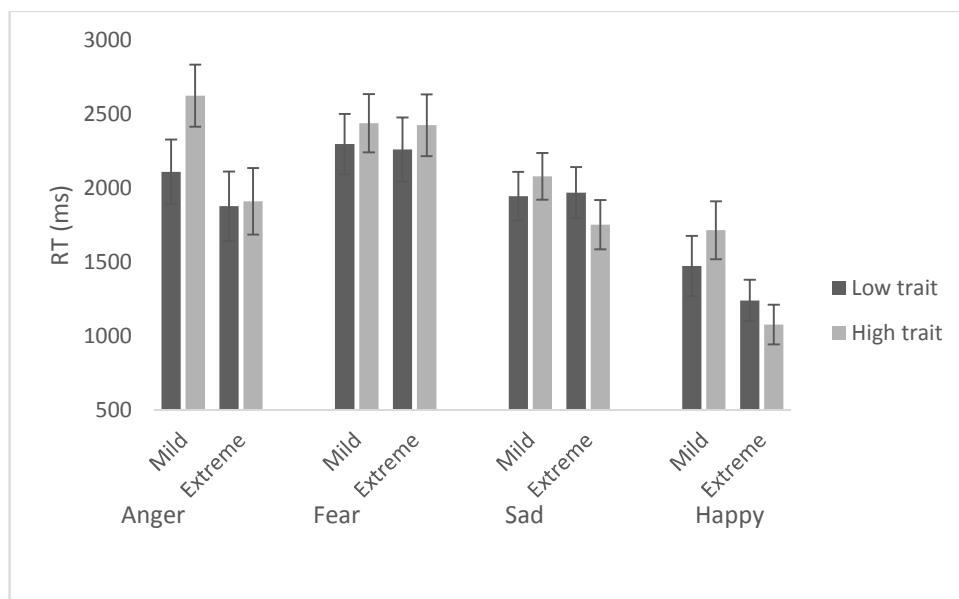
An independent samples t-test investigating the effect of Group on the perception of a neutral face found no difference in accuracy scores between the two groups ( $t(48) = 1.34$ ,  $p > .05$ ).

#### *Reaction Time Data (6.4.2)*

The reaction time data was entered into a 4 x 2 x 2 repeated measures ANOVA with Emotion (Happy vs Anger vs Fear vs Sadness) and Representation (Mild vs Extreme) as the within factors and Group (High AQ vs Low AQ) as the between subjects factors. Again, neutral faces were analysed separately as they did not have both a mild and an extreme representation.

The analysis found a significant main effect of Representation ( $F(1,47) = 14.07, p < .001$ ), which revealed that participants took longer to identify Mild representations of emotions than Extreme representations of emotion. There was also a main effect of Emotion ( $F(3,144) = 29.00, p < .001$ ). Post-hoc tests showed that following a Bonferonni correction, Happy emotions were responded to significantly more quickly than all other emotional expressions and that Sadness was responded to significantly more quickly than Fear and Anger expressions (all  $p$ 's  $> .05$ ). There was no main effect of Group ( $F(1,47) = .31, p > .05$ ). A trend towards significance was found for the interaction between Representation and Emotion ( $F(3,144) = 2.54, p = .059$ ). Post hoc paired samples t-tests with a Bonferonni correction showed that participants took longer to identify Mild representations of Happy, Anger and Sadness (all  $p$ 's  $< .05$ ), but there was no difference found for response times for Mild and Extreme representations of Fear.

The interaction between Group and Representation reached significance ( $F(1,47) = 4.42, p < .05$ ). This interaction was driven by the High AQ Group taking longer to respond to Mild representations of emotion than the Low AQ group. There were no interactions found between Group and Emotion ( $F(3,144) = .75, p > .05$ ) or between Group, Representation and Emotion ( $F(3,141) = .67, p > .05$ ) (fig 6.3)



*Figure 6.3.* Bar chart highlighting the differences in reaction time data for mild and extreme representations of the emotional faces used in the current study.

#### *Error Analysis (6.4.3)*

Error analysis conducted in order to investigate whether when participants made errors on this task, would the pattern of errors differ between the high and low autism trait group. For this analysis, the number of emotions incorrectly identified as neutral was assessed between the two groups based on Neves et al., (2011). In particular, it was important to see if the high ASC-trait group failed to accurately perceive valence on faces that were expressing emotion. For each different emotional expression, incorrect response where participants responded that the stimuli was not displaying an emotional expression was used for this analysis. Individual ratio scores were created for each expression and representation strength for each participant. This score was calculated by dividing the number of each emotional expression that they classed as having no expression by that individual's total number of errors. By doing this, each participant was given a score which reflected the proportion of their errors that related to judging expression stimuli as having no valence.

As the data was not normally distributed, non-parametric statistics were used. A Scheirer-Ray-Hare test was conducted with two levels of Group (High AQ vs Low AQ) and four levels of Emotion (Happy vs Anger vs Fear vs Sadness) for mild emotional expression error data only. This analysis revealed a significant main of Group ( $\chi^2(1) = 6.08, p < .05$ ) which showed that the High AQ group erroneously perceived more subtle emotional expressions as neutral than the Low AQ group. No main effect of Emotion ( $\chi^2(3) = .01, p > .05$ ) or interaction between Group and Emotion were found ( $\chi^2(3) = 2.22, p > .05$ ) (fig 6.4).



*Figure 6.4.* Bar chart detailing the number of times that participant's erroneously labelled a subtle expression as having no expression. This is expressed as a function of the total errors each participant made.

## Discussion (6.5)

The current study found that people with high and low traits of ASC showed no difference in their ability to recognise the expressions of others, regardless of the intensity in the expressional information displayed on the face. However, those with high ASC-traits took longer to make judgements regarding mild emotional expression faces and when they were incorrect in their assessment, were more likely to think mild expressions had no valence compared to low ASC-trait individuals.

The current results suggest that the adaptation findings in chapter 3 are unlikely to be due to an inability of those high in ASC-traits to perceive emotion expression adaptation aftereffects. This is because the current study showed no overall difference in accuracy scores when judging emotional expressions and it is unlikely that the high ASC-trait participants in chapter 3 would not be able to identify an emotional expression had it been correctly represented. However, the current results support the interpretation that, when errors were made in the adaptation task, this is likely to be that the high ASC-trait group did not recognise the adaptation aftereffect as having any valence, as shown in the error analysis of the current study. Combined with the results of chapter 3 it seems likely that high ASC-trait individuals could have difficulty in creating representations of the mild negative emotional expressions aftereffects during adaptation and negative expressions would appear to have limited valence to these individuals.

As no difference in emotion recognition capability for the two groups arose for accuracy when judging mild and extreme representations of emotional expressions, this could reflect a similarity in emotion recognition ability between the two groups. There are a number of studies in ASC that have reported little or no differences in emotion recognition with controls. For example, in a meta-analysis by Jones et al. (2011) cross-modal emotion recognition in those with ASC, including facial emotion and auditory perception of emotional voices, was found to be no different from that of control participants when assessed across multiple studies. The work by Jones et al., suggests that people with ASC may have the ability to recognise emotional information, however they don't not use this in an appropriate way in their day-to-day lives. This would lead to the disconnect seen between the literature which reports mixed findings with regards to emotional expression processing and the clinical reports of ASC that purport impairments with real world social interaction. The real world social interaction difficulties could be a product of slower emotion perception ability in ASC. Research assessing emotion processing in those with high ASC-traits also show mixed results which could be a product of a similar disconnect

between ability and functioning. The current results support this as the participants in the current study were able to recognise emotional expressions, however they showed a delay when responding to mild emotion expression information and had different patterns of errors.

A delayed response time for social information is consistent with previous work assessing emotion recognition in the BAP, where parents of ASC individuals have also been shown to take longer to respond to emotion expression information (Neves et al., 2011). The delayed response when responding to emotional expressions in high ASC-trait individuals was seen even though all participants saw the stimuli for the same amount of time (300 ms). The delay in response time does not suggest that these individuals need more emotional expression information obtained through longer exposure to the stimuli as suggested in Poljak et al., (2012). Instead, the results of the current study suggests that although those with high-ASC-traits are able to accurately identify emotional expressions to a similar extent to those with fewer traits, they need longer to process this information subsequent to seeing it. This could mean that these individuals are not making automatic assessments of facial emotion information and instead may be systematically and cognitively deducing the meaning of facial information. This interpretation is supported by ASC research that shows that people with ASC evaluate facial emotion stimuli using a rules-based strategy to decode facial expression information (Rutherford & McIntosh, 2007). A rules-based strategy is more time consuming and would lead to a similar effect seen in the current study. A rules-based strategy is more likely in high systemisers who have an effortful cognitive processing style (Baron-Cohen, 2006a, 2006b, 2009). This style involves understanding the relationships between an objects component parts in order to piece together the meaning behind it. Systemising has been shown to be higher in people with ASC and those with greater ASC-traits. People who systemise are thought to show increased deliberation on tasks (Brosnan, Hollinworth, Antoniadou, & Lewton, 2014) which could also help explain the increased reaction time for mild representations of emotional expressions seen in the high ASC-trait group.

Interestingly the reaction time differences only occurred for mild emotional expression information. This suggests that any difference in the way people with high ASC-traits assess emotional expression information is subtle and only occurs when information is limited. Perhaps when presented with extreme emotional expression information high ASC-trait individuals use a typical method of identifying emotional expressional information,

however when information is more limited, these individuals need to rely on compensatory mechanisms in order to reach an adequate conclusion.

One of the most interesting results to arise from the current study is that, although no explicit group differences in accuracy were found between the two groups, when errors were made, the high ASC-trait group were more likely to perceive a mild emotional expression as having no valence than those with fewer traits. This suggests that when those with high ASC-traits do make an error, it is not due to a confusion between different types of emotional expression, but more likely due to not being able to detect the valence of the expression. This supports the idea of a rules-based strategy being used for emotional expression recognition in these individuals as under this interpretation without sufficient emotional expression information, facial emotion expressions will not cross a threshold that allows meaningful interpretation as an expression.

Another explanation is that the lack of group differences could have arisen through the methodological differences between this study and previous other studies. One factor that could have obscured a result is the stimuli presentation time. In order to increase the similarity between the current study and the adaptation study presented in chapter 3, a presentation time of 300 ms was used. It is possible that this presentation time was too fast and as a result worsened performance in the low ASC group to a point where the two groups' performance was indistinguishable. However, looking at the raw accuracy data for the current study it is clear that this is not the case as all response means are well above chance level. Perhaps emotion recognition difficulties in the BAP and the WAS are too subtle to detect using labelling paradigms whereas in clinical populations issues with emotion expression identification are more readily observable. This is highlighted by the difference in the current study between the equal results found between group's identification on accuracy scores and the slower reaction time for high ASC-trait individuals when assessing mild emotional expressions. Future research should look at new ways of assessing emotion expression processing difficulties that can identify the subtle differences and explore the mechanisms that drive them.

An implementation for future research that would help understand the mechanisms underlying the differences in reaction time observed in the current study would be to employ post presentation masking on a number of presentation trials. This is a technique that has been under used in this field and could help explore emotion recognition to a greater extent in the WAS. The high ASC-trait group in the current study were not impaired

at identifying expressions compared to the low ASC group but had longer reaction times for mild expression stimuli. Using a masking paradigm would prevent the emotion expression stimuli from entering sensory memory (Atkinson & Shiffrin, 1968; Baddeley & Hitch, 1974) and would prevent the use of a rules-based strategy. If this group are using a rules-based strategy involving residual memory of the expression, a masking paradigm would be expected to lower accuracy for emotion expression identification in those with high ASC-traits as they would not be able to use their sensory memory to “piece together” the expressional information. This would also inform as to whether different strategies are used for extreme vs mild emotion expression stimuli as under a rules-based model accuracy for both would be assumed to suffer following implementation of a masking paradigm.

One interesting result that arose from this, however, was that regardless of group membership, all participants were better at identifying even mild depictions of fear than other negative emotions. This is an interesting result as it supports ideas that threat stimuli have perceptual advantages because of evolutionarily developed mechanisms for survival (Ohman, 1996). Even mild fear stimuli are more easily distinguishable than other mild expressions. As fear can signal the presence of threat, being able to pick up on this stimuli even with little emotional information would be evolutionarily advantageous. However this result was only found at trend levels so further research needed to understand this further.

In conclusion, the current study did not find reduced recognition of mild emotions in those with high traits of ASC as other studies have reported. However, those with high ASC-traits took longer to classify mild emotional expressions and when they made an incorrect judgement, were more likely to report perceiving no valence. These results support the findings from Chapter 3. Although people with high ASC-traits were no worse at interpreting mild expressions, they were more likely to label subtle expressions as neutral. This could arise from an under developed system to represent emotional expressions which would lead to less perceptual difference between subtle and neutral expressions for this population.



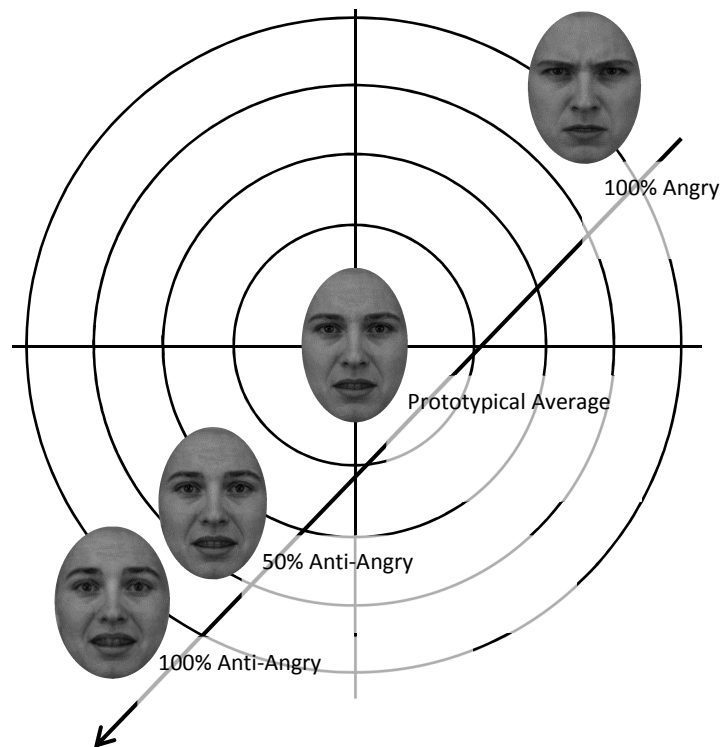
# **Chapter 7 – Study 5 –**

## **Using Visual Adaptation to Explore the Mechanisms of Emotion Processing in ASC**

### **Introduction (7.1)**

In Chapter 3 it was found that individuals with high levels of ASC-traits have difficulty accurately identifying aftereffects that typically have a negative valence. People with ASC often have difficulty with negative emotional expressions. The link between the WAS and the clinical phenotype of ASC can be explored by using visual adaptation to investigate whether or not a similar emotion expression representation difficulty exists in people with ASC.

As explained in Chapter 3, people generally represent emotional expressions with reference to a prototype 'norm'. This adaptive system suggests that each individual has a prototypical 'norm', which is an average expressionless facial representation. The prototypical norm lies in the centre of their representational face space. Emotional expressions are represented as deviations in face space from the prototypical norm. Evidence for this comes from using anti-expression adaptation stimuli in paradigms run using typical controls, with anti-expressions being computationally derived facial expressions that represent the location in face space that is directly opposite to a specific emotional expression. Skinner and Benton (2010) found that following adaptation to an anti-expression, participants were more likely to perceive a neutral target face as having the 'typical' expression that appears on the corresponding opposite side of the face space to the anti-expression (fig. 7.1).



*Figure 7.1.* A representation of the 'Face space' which shows how expressions and other facial information can be represented as deviations from an average, prototypical norm

Juricevic and Webster (2012) showed that there were no facilitation or suppression effects for any particular emotional expression stimuli other than the adapting expression. Therefore, if participants were adapted to an anti-happy expression, then perceptual aftereffects only altered perceptions of happy expressions and did not affect the perception of subsequently presented expressions of other emotions. The specificity of these results between adapting stimulus and the resulting perceptual illusion suggests that emotion expression representation is a selective process that temporarily renormalizes the visual system around that adapted expression. The process of renormalisation affects only the representational space relating to emotional expression that was adapted to. This suggests that the face space contains specific trajectories along which the intensity of specific emotional expressions are represented (see fig 7.1). Adaptation along specific face space trajectories is beneficial as it can leave other expression representations unaltered and help to probe how the brain represents specific emotional expressions.

Paradigms involving Adaptation aftereffects have previously been used to assess the representations of the social world in those with ASC. For example, Pellicano et al. (2007) adapted children with ASC and controls to typical-identities and anti-identities. The results showed that the ASC group were not different to controls overall in identifying faces.

However, the ASC children showed a reduced accuracy in identifying the aftereffects evoked through adaptation. The results show atypical adaptation mechanisms for face identification in ASC, which suggests they have difficulty in representing facial information. This is because there were no differences in general face identification, only in the perceptual aftereffects that involve areas of the brain that create facial representations. However, the study involved face identification and did not include facial expressions of emotion. Additionally, this study used child participants who are still developing their representational face-space. There could be differences in the development of this face-space with more experience and, as such, it is also important to use adult participants.

Unlike facial identity, which is relatively stable over time, emotional expressions are transient over time. Similar differences in adaptation mechanisms in those with ASC for face identity could also underlie the difficulty these individuals have with understanding the emotional expressions of others. The first study to assess this was Rutherford, Troubridge and Walsh (2012), who adapted adults with ASC to basic emotional expressions prior to exposure to a neutral face. The results showed that, although those with ASC showed evidence of an adaptation aftereffect, they had reduced accuracy in correctly labelling the expression aftereffect compared to control participants. More specifically, whereas in typical individuals adaptation to a negative expression usually evokes a positive valence aftereffect, people with ASC reported a negative emotion aftereffect following adaptation to a negative expression. This shows atypical adaptation mechanisms to negative emotional expressions in ASC, suggesting they are representing negative emotional expression information in a different way to controls.

However, in the Rutherford et al., (2012) study participants had to choose between six basic emotions on each trial to label the afterimage. As ASC individuals have problems in executive functioning (Ozonoff & Jensen, 1999), it is uncertain whether the results represent a more general problem in responding or may reflect a difference in adaptation behaviour. Since negative basic emotions are generally harder to label than positive emotions as there are more example of negative expressions (e.g. Ekman & Friesen, 1971), this general problem may just have been more evident on the difficult trials involving adaptation to negative emotions. People with ASC also show deficits in labelling some of the various basic emotional expressions, which is more evident for negative expressions (Ashwin, Chapman, et al., 2006). This means that requiring them to explicitly label all the basic emotions in an adaptation task may produce differences in responding that are due to verbal demands of labelling the emotions within a fast experimental design, rather than

in representing the facial expression. Using a task that had fewer response choices would reduce the cognitive demand required by those with ASC. Additionally, using fewer choice options of emotions rather than many labels would help reduce the effects of any difficulties in producing verbal labels for expressions.

More recently, Cook, Brewer, Shah, and Bird (2014) developed a series of emotional expression photos derived from 2 emotional expressions morphed along a continuum from disgust to anger. This created an array of stimuli that represented a continuum from disgust to anger in 10% steps. These stimuli were then used to assess how different expression strengths of adaptation stimuli effect the adaptation aftereffect seen in those with ASC compared to controls. This study included a choice of only two emotional expressions when labelling the adaptation aftereffect, either disgust or anger. Fewer choice options means that any general difficulties in executive function or verbal labelling of basic emotions is less likely to have effects on the results. Cook et al., reported no difference in accuracy between controls and ASC participants in their perceptual aftereffects to the target face following adaptation, showing that the adaptation mechanisms for representing certain negative facial emotion expressions could be intact in those with ASC when the issue of labelling is reduced if not eliminated.

A key difference between studies that report a deficit in adaptation mechanisms to social (or facial) information in ASC (Pellicano et al., 2007) and those that have previously explored emotion expression adaptation in ASC (Cook et al., 2014; Rutherford et al., 2012) is the stimuli utilised. Where Cook et al., and Rutherford et al., utilise stimuli that represented typical expressions as adaptation stimuli (e.g. disgust, anger, happy etc), Pellicano et al., used anti-identity stimuli in order to probe the representation of social information in those with ASC. Anti-identities and anti-expressions are created to be the morphological opposites of typical expressions in the face-space theory of facial representations. The aftereffects induced through adapting to the anti-stimuli have been shown to match well with the expression or identity it was created from on the opposite directional side within the face space. The typical representations of basic emotions, such as those used in Cook et al., (2014) and Rutherford et al., (2012) do not have a natural opposite example or expression that appears within the face space. Although an aftereffect image of a happy expression may appear negative in valence, the aftereffects that appear from these basic emotions have no actual verbal emotional label. Given the difficulties in attaching a verbal label to emotion expression stimuli in ASC and that the atypical expression aftereffects arising in cook et al., and Rutherford et al., it is difficult to

investigate the underlying mechanisms associated with emotion expression representation and understanding the results from experiments limited to these stimuli.

In addition to issues with the ability to verbally label stimuli, previous studies (Cook et al., 2014; Pellicano et al., 2007; Rutherford et al., 2012) did not use a control condition for non-social adaptation ability. It is not possible to infer that emotion expression adaptation difficulties in ASC are specific to social stimuli and may simply reflect a general adaptation deficit. Using a non-social adaptation control task could help understand the specificity of adaptation difficulties in ASC. Using a non-social task also helps to test the social motivation theory of ASC. The social motivation theory would suggest that the representational systems for social stimuli should be underdeveloped in ASC due to a lack of drive to attend to such stimuli reducing the experience ASC individuals have with these stimuli. However, no such deficit would be expected when adapting to non-social stimuli as the drive to attend to such stimuli is not predicted to be impaired.

The present study aimed to address some of the limitations of previous emotional expression adaptation studies by using both typical and anti-expression stimuli of positive and negative emotions. It is proposed that anti-expression stimuli are better able to probe the underlying mechanisms associated with the representation of emotional expressions in ASC due to their specific relationship with typical-representations of emotional expressions. We also do not normally see anti-expressions in real life, so using these stimuli will test emotional processing that has not been affected by learning or life experiences through repeated exposures in the same way that this could occur with typical, basic emotional expressions. Stimuli with two different strengths will be used in order to test whether people with ASC are able to utilise a prototype referenced model of emotion expression representation (see chapter 3). Further to this, typical expressions will also be employed in order to assess any difference between using anti-expressions and typical-expressions in this population. The choice options for the perception of the afterimages were limited to either positive or negative valence, to reduce the cognitive task demands and to limit the effects of any verbal-labelling difficulties on responding to perceptual aftereffects. A non-social control condition involving the tilt aftereffect was used to test whether people with ASC show general adaptation differences, or whether they are specific to facial emotional expressions and further, a test of basic emotion expression identification was included to help infer how the deficits in basic emotion perception may compare to any deficits in emotion expression adaptation.

## **Aims and hypothesis (7.2)**

The aims of the current experiment are to explore (1) if there are differences in perceptual afterimages from adaptation to emotional expressions in ASC vs controls, (2) whether any differences are valence specific, (3) whether there are differences in emotion recognition ability in ASC vs controls and (4) if emotion recognition ability relates to ability to accurately identify aftereffects arising from adaptation. Finally the current study aims to explore (5) whether there are differences in non-social adaptation ability.

In line with the social motivation theory of ASC It is hypothesised that (1) the ASC group would show differences in emotion expression adaptation compared to controls and (2) more specifically that differences would be more evident for negative afterimages than positive ones. Further to this, due to an under-developed representational system for emotional expressions it is hypothesised that (3) emotion recognition ability would differ between ASC and control participants and (4) that emotion recognition ability would correlate with accuracy on emotion expression adaptation task. Finally, as the social motivation theory predicts a lower drive for social but not non-social stimuli, it is hypothesised (5) that the ASC group would show no difference to control participants following adaptation to non-social stimuli, showing that issues are specific for expression representation.

## **Methods (7.3)**

### *Participants (7.3.1)*

Twenty-two participants with ASC and 22 control participants were recruited for this study. One ASC participant was removed prior to analysis as they were unable to complete the adaptation task. This left a final sample of 21 ASC participants (7 female) and 22 control participants (7 female). ASC participants had a mean AQ of 31.71 (SD = 8.26, range 20-46), a mean age of 27.58 years (SD = 8.73; range 18-44) and mean full-scale IQ of 113.06 (SD = 7.59; range = 95-127). Control participants had a mean AQ of 17.45 (SD = 5.95, range = 5-28), a mean age of 25.95 (SD = 5.74, range 18-45) and a mean IQ of 113.45 (SD = 7.76, range = 99-126). There were 43 participants in total.

### *Stimuli (7.3.2)*

#### *Full Face Emotion Recognition (7.3.2.1)*

84 photos of emotional expressions were taken from the KDEF facial set (Lundqvist et al., 1998). There were 12 examples of each of the 7 expressions; Anger, Fear, Disgust, Happy, Sad, Surprise and Neutral. The images were depicted by white male and female actors with half of the stimuli in each expression condition being presented by each gender of actor. All stimuli were of actors expressing one of the 7 expressions and facing the camera. Stimuli were made greyscale and matched for average luminance using a histogram matching procedure in Photoshop.

#### *Tilt aftereffect (7.3.2.2)*

The same stimuli as used in chapter 3 consisting of 6 arrays of tilted lines and one test array of vertical lines were used in the present study.

#### *Adaptation task (7.3.2.3)*

The same stimuli as used in chapter 3 consisting of a 100% strength adaptation stimuli for each of typical-happy, anti-happy, typical-anger and anti-angry expressions, a 50% adaptation stimuli for both anti-happy and anti-angry and the prototypical average test face were used in the present study.

## **Procedure (7.3.3)**

### *Full face emotion recognition (7.3.3.1)*

All tasks presented to participants in a quiet room on the University of Bath campus in the CASTL labs. for each trial, participants were initially presented with a fixation cross for 500 ms, followed immediately by a photo of an emotional expression for 300 ms. After the emotional expression display, participants were then presented with a screen of response options, which included Anger, Fear, Disgust, Happy, Sad, Surprise and Neutral. Response options were labelled from 0-6, with a number corresponding to each emotion option. Participants were required to use the keypad to the right of the keyboard in order to make their choice about what expression the preceding face was displaying. The response options were displayed until the participant made a response or for a maximum of 10000 ms if no response was made. When a response was made or after 10000 ms the trial ended. A blank screen appeared for 500 ms as an ISI, and then the next trial began. There were 12 trials for each of the 6 basic emotions (Happy, Sadness, Fear, Surprise, Anger and Disgust) and 12 neutral expression stimuli presented in a random order. This task took approximately 5 minutes to complete

#### *Tilt aftereffect (7.3.2.2)*

The procedure for this task was the same as in chapter 3.

#### *Adaptation task (7.3.2.3)*

The same procedure for this task was used as in chapter 3.



## Results (7.4)

### Full Face Emotion Recognition (7.4.1)

A 7x2 repeated measures ANOVA with within subjects factors of Expression (Anger vs Fear vs Sadness vs Disgust vs Happy vs Surprise vs Neutral) and a between subjects factor of Group (ASC vs Control) was conducted on emotion recognition accuracy data. Results revealed a main effect of Expression ( $F(6,252) = 58.44, p < .01$ ), with Happy being more accurately recognised than all other expressions bar Neutral, Sadness being recognised more accurately than Fear, Anger and Disgust; Surprise being recognised more accurately than Fear and Anger; Disgust and Anger being more accurately recognised than Fear. Neutral was recognised more accurately than Anger, Fear and Disgust. (see table. 7.1). There was also a main effect of Group ( $F(1,42) = 8.44, p < .01$ ). The main effect of Group showed that the ASC group performed more poorly at expression recognition (72.0%) overall than the control participants (81.4%).

Table 7.1.

*Accuracy scores in percent (sd) for 6 basic emotional expressions for ASC and Control groups*

Emotion	ASC	Control	Statistic
Anger	60.19 (26.37)	81.22 (17.46)	$p = .003^*$
Disgust	69.86 (25.08)	84.35 (13.70)	$p = .021^*$
Fear	43.76 (25.58)	41.61 (23.33)	$p = .772$
Happiness	94.90 (8.11)	99.65 (1.67)	$p = .009^*$
Sadness	84.24 (20.79)	93.87 (8.79)	$p = .043^*$
Surprise	79.00 (16.56)	87.78 (11.54)	$p = .046^*$
Neutral	88.19 (20.90)	93.48 (8.75)	$p = .272$

An interaction between Group and Emotion was discovered ( $F(6,252) = 2.44, p < .05$ ). Post-hoc planned comparisons involving independent samples *t*-tests were carried out for each of the seven expressions. Results showed the ASC group were had reduced accuracy Angry

( $t(42) = -3.14, p < .05$ ), Disgust ( $t(42) = -2.41, p < .05$ ), Happy ( $t(42) = -2.75, p < .05$ ), Sadness ( $t(42) = -2.08, p < .05$ ) and Surprise ( $t(42) = -2.06, p < .05$ ) expressions. However, no significant group differences were found for Neutral or Fear expressions (all  $p$ 's  $> .05$ ).

#### **Tilt Adaptation Baseline Task (7.4.2)**

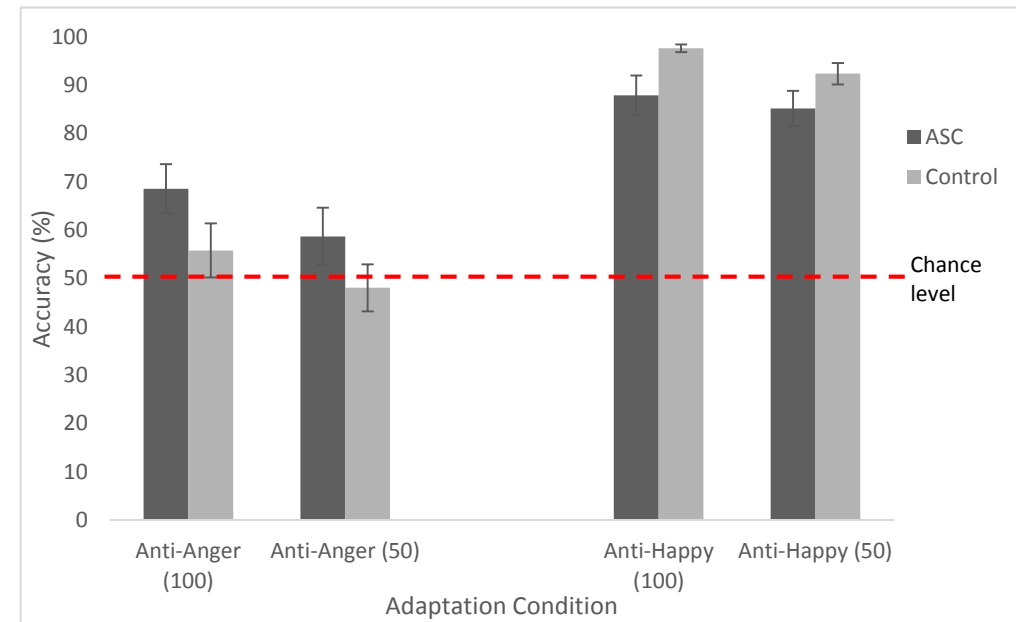
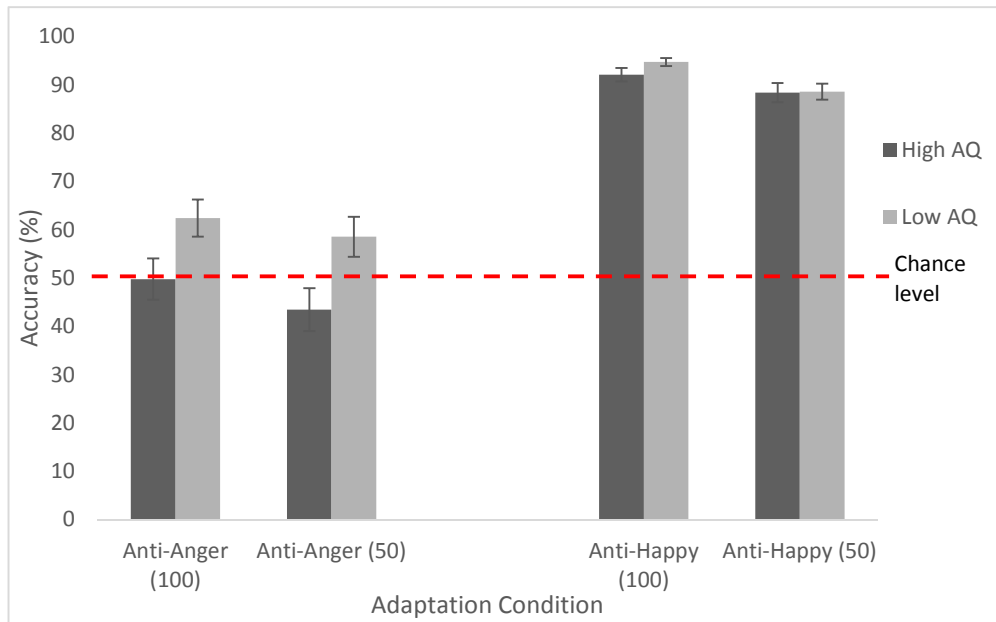
In order to assess whether the basic mechanisms for visual adaptation are intact in those with ASC, a repeated measures ANOVA was conducted on correct response data from the tilt adaptation task. The within subjects factors were Adaptation Stimuli Orientation (Left vs Right) and Degree of Tilt ( $5^\circ$  vs  $15^\circ$  vs  $25^\circ$ ) and the between group factor was Group (ASC vs Control). Results showed that there were no main effects of Group ( $F(1,32) = .18, p > .05$ ) or Adaptation Stimuli Orientation ( $F(1,32) = .62, p > .05$ ). No significant interactions were found between Group and Adaptation Stimuli Orientation ( $F(1,32) = 1.53, p > .05$ ), or between Group and Degree of Tilt ( $F(2,64) = .44, p > .05$ ). A Main effect of Degree of Tilt arose ( $F(2,64) = 3.92, p < .05$ ). Post hoc tests exploring the difference between Tilt conditions revealed aftereffect accuracy was better for  $5^\circ$  adaptor stimuli than it was for  $25^\circ$  adaptor stimuli ( $p < .05$ ). And a trend towards significance arose for the  $15^\circ$  adaptor stimuli accuracy being greater than  $25^\circ$  adaptor stimuli ( $p = .066$ ). This result was expected based on previous literature (Clifford & Rhodes, 2005; Gibson & Radner, 1937).

#### **Emotion Expression Adaptation (7.4.3)**

##### *Anti-expressions at 50% and 100% representational strength (7.4.3.1)*

The DV in this part of the study was whether the valence of the aftereffect was perceived in the expected way based on previous research, with the choices being either positive or negative valence on each trial. For the trials where the Angry and Anti-happy expressions are the adapting stimuli, the perceptual aftereffect normally involves a positive valence. In the trials with the Happy and Anti-angry expressions as the adapting stimuli, this normally produces a perceptual aftereffect that is negative in valence. Firstly, a repeated measures ANOVA was conducted on the anti-expression data only. This split was used as anti-expression data had both 50% and 100% strength adaptation stimuli. Typical-expression data only had 100% strength adaptation stimuli and was not used for this analysis. Within subjects factors of Aftereffect Valence (Positive vs. Negative) and Representational Strength (50% vs. 100%) and a between-subjects factor of Group (ASC vs Control) were used to analyse the accuracy data.

Results found a main effect of Aftereffect Valence ( $F(1,42) = 55.87, p < .01$ ), with accuracy being higher for aftereffects arising from Anti-Happy adaptation stimuli than those arising from Anti-Angry adaptation stimuli. These results showed that regardless of group membership, all participants were able to more accurately identify aftereffects arising from Anti-Happy adaptation stimuli (90.8%) than Anti-Angry adaptation stimuli (57.8%). There was also main effect of Strength ( $F(1,42) = 21.13, p < .01$ ), with all participants able to more accurately identify aftereffects arising from 100% strength adaptation stimuli (77.5%) than 50% strength adaptation stimuli (71.1%). Additionally, a significant interaction between Group and Aftereffect Valence was revealed ( $F(1,42) = 5.215, p < .05$ ; fig 7.2).



*Figure 7.2.* (a) Data from Chapter 3 showing proportion of predicted responses for High and Low AQ Groups on Anti-Angry and Anti-Happy adaptation trials, adapted to match format in current study. (b) Proportion of predicted responses on adaptation aftereffect task for the ASC and Control groups for Anti-Angry and Anti-Happy adaptation trials.

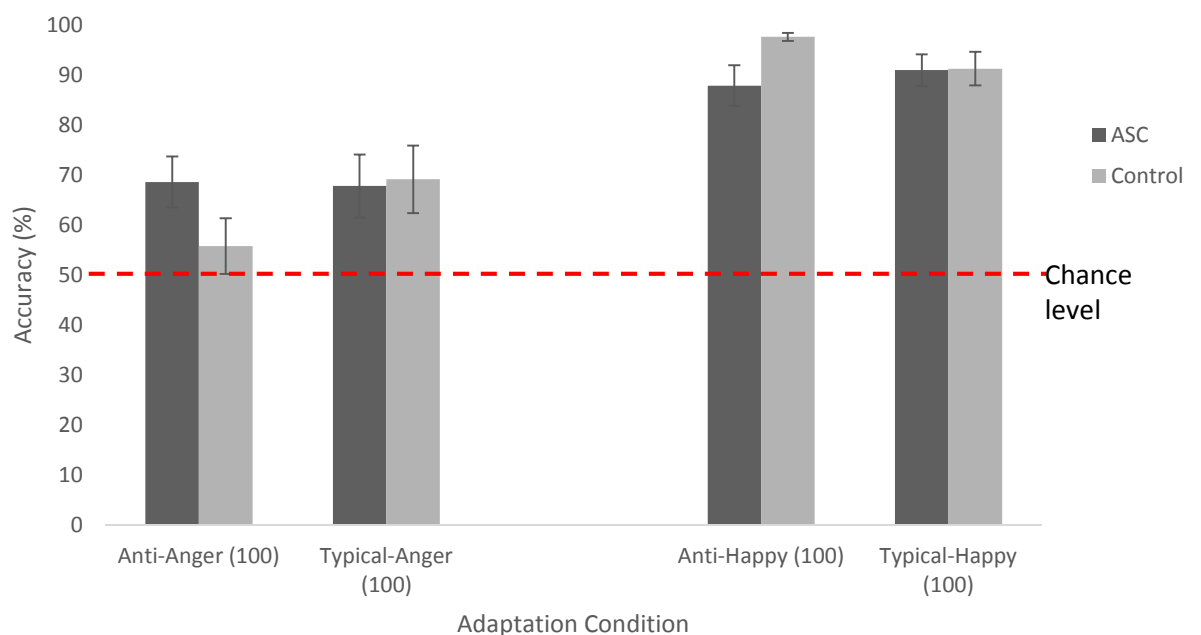
In order to explore the interaction further, it was broken down further by Valence with a 2x2 repeated measures ANOVA analyses with the within subjects factor of Representational Strength (50% vs. 100%) and the between-subjects factor of Group (ASC vs Control) for each of the positive and negative afterimages separately. For both analyses, a main effect of Representational Strength was found showing better performance for judging aftereffects arising from 100% representational strength adaptor images than 50% strength adaptor stimuli (all  $p$ 's < .05). For Anti-Happy expressions a main effect of Group was found ( $F(1,42) = 4.88, p < .05$ ) showing that the control group more accurately identified the positive valence aftereffects arising from Anti-Happy adaptation stimuli (95.0%) than the ASC group (86.6%). However, when assessing Anti-Angry expressions no main effect of Group was revealed ( $F(1,42) = 2.66, p > .05$ ). No significant interactions arose from either analysis (all  $p$ 's > .05).

To assess whether accuracy was significantly different from chance levels for each group, one-sample  $t$ -tests were performed with a critical value of 50% accuracy for conditions of 50% and 100% representation strength for both Anti-Happy and Anti-Angry expressions. This found that the ASC group fared no better than chance when identifying aftereffects arising from 50% Anti-Angry adaptation stimuli ( $t(20) = 1.48, p > .05$ ) but performed better than chance responding to aftereffects arising from 50% Anti-Happy adaptor images and both 100% strength anti-expression stimuli ( $p$ 's < .05). Interestingly, the Control group fared no better than chance level when identifying aftereffects arising from the 50% ( $t(21) = -.39, p > .05$ ) and 100% ( $t(21) = 1.04, p > .05$ ) Anti-Angry adaptation (fig 7.1), but performed better than chance on both 50% and 100% Anti-Happy trials ( $p$ 's > .05).

#### *Anti-expressions and typical expressions analysis (7.4.3.2)*

To test whether adaptation aftereffects are induced more strongly by anti-expressions than typical expressions in ASC and control participants, a further analysis assessed the participant's responses to 100% anti-expressions and their corresponding typical expressions. 50% adaptation strength stimuli were not used here as there were no corresponding 50% adaptation stimuli for typical-expressions used in the current study. A repeated measures ANOVA with the within subjects factors of Representation (Typical-representation vs Anti-representation) and Aftereffect Valence (Negative Aftereffect vs Positiveaftereffect) and between subjects factors of Group (ASC vs Control) was used. This analysis found no overall main effect of Group ( $F(1,42) = .01, p > .05$ ), Representation

( $F(1,42) = .65, p > .05$ ) or Aftereffect Valence ( $F(1,42) = 1.04, p > .05$ ). There was no interaction of Group and Representation ( $F(1,42) = .19, p > .05$ ) or Group and Aftereffect Valence ( $F(1,42) = 2.24, p > .05$ ). However, an interaction between Aftereffect Valence and Representation was revealed ( $F(1,42) = 83.63, p < .001$ ) and there was a trend towards a three-way interaction between Group, Aftereffect Valence and Representation ( $F(1,42) = 3.22, p = .08$ ). This was broken down into two smaller 2x2 repeated measures ANOVAs for each of the aftereffect Representation factors that used within subjects factor of Aftereffect Representation (Typical-representation vs Anti-representation) and a between subjects factor of Group (ASC vs Control). These analysis showed that for Representations that create negative valence aftereffects (Happy and Anti-Angry), a main effect of Representation was found showing that the Typical-expression representation (i.e. Happy expressions) led to a stronger aftereffect than the Anti-expression representation (i.e. Anti-Angry expressions) ( $F(1,42) = 53.23, p < .001$ ). For this analysis there were no other main effects or interactions ( $p$ 's  $> .05$ ). The analysis for stimuli that lead to positive valence aftereffects (Angry and Anti-Happy), a main effect of Representation was also found showing that Anti-expression representations (i.e. Anti-Happy) led to a stronger effect than Typical-expression representations (i.e. Angry) ( $F(1,42) = 28.31, p < .001$ ) For this analysis there were also no other main effects or interactions ( $p$ 's  $> .05$ ) (fig 7.3).



*Figure 7.3.* Adaptation aftereffect accuracy for ASC and Control groups for Anti- and Typical-expression adaptation trials.

#### *Possible contribution of emotion expression recognition ability (7.4.3.3)*

Correlation analysis was conducted for each of the groups independently. For the Control group, no correlations existed between emotion recognition and aftereffect identification. However the ASC group showed a significant positive correlation between average score on the adaptation task and average score on the full face emotion recognition task ( $r=.598$ ,  $n=21$ ,  $p<.01$ ). Positive correlations also existed between ability on Anti-Angry adaptation trials and Angry facial expression identification ( $r=.589$ ,  $n=21$ ,  $p<.01$ ) and interestingly between ability on Anti-Happy trials and the ability to correctly identify a face as neutral ( $r=.504$ ,  $n=21$ ,  $p<.05$ ).

## Discussion (7.5)

The current study found that people with ASC had reduced accuracy compared to controls for labelling the valence of perceptual afterimages resulting from emotion expression adaptation, but only for anti-happy expression adaptation. This finding is unlikely to have emerged from a general deficit in adaptation mechanisms in ASC, as they showed comparable performance to controls for negative valence afterimages and no group differences were found in the low level non-social visual adaptation task. However, the ASC group had reduced accuracy compared to controls at verbally labelling emotional expressions from photos, with less accuracy on emotion expression labelling associated with worse perception of the valence of emotional afterimages. All participants were found to have better skill at identifying images arising from 100% strength adaptation images compared to 50% adaptation images with no differences between groups on this task. In addition, the results showed that regardless of group, all participants were better able to identify aftereffects arising from typical-expressions of happy compared to anti-expressions of anger and were better able to identify aftereffects arising from anti-expressions of happy compared to typical-expressions of anger. This suggests that it is easier to represent emotions that relate to happy expressions than angry expressions regardless of diagnosis.

The ASC group had reduced proportion of responses in the predicted direction compared to controls in perceiving the valence in visual afterimages, but this effect was only seen for afterimages arising from anti-happy stimuli which typically have a positive valence. This was similar to Rutherford et al., (2012) in that ASC participants showed specific differences to controls in perceiving the emotion in afterimages, but only for a specific valence. The present findings showed that this was different for positive valenced aftereffects. This is similar to the results found by Rutherford et al., where group differences showed that people with ASC were more likely to judge aftereffects that normally have a positive valence as having a negative valence compared to controls. The replication of the results found in Rutherford et al., are interesting as the current study asked participants to rate the valence of the aftereffect rather than to verbally label the emotion. A potential limitation of Rutherford et al., was that the typical-expression verbal labels used to identify the aftereffects evoked by adapting to typical-expression adaptation stimuli do not typically correspond with the aftereffect that is generated. In addition to this, people with ASC have been found to perform worse than controls when using verbal labels to identify specific emotions. Here, valence options (positive and negative) were used instead of specific verbal labels for facial expression aftereffects. The replication of Rutherford et al's., results



therefore supports that those with ASC do indeed have difficulty with the positive valence aftereffects which arise from adaptation to negative valence adaptation stimuli.

However, the effect seen in the current study was not reflective of the results found in individuals with high ASC-traits in the typically developing population (chapter 3). People with high ASC-traits were previously found to have no group differences compared to those with fewer traits when identifying positive aftereffects arising from anti-happy stimuli, but instead had relative difficulty identifying aftereffects that generally have a negative valence arising from anti-angry stimuli. It was hypothesised here that if the ASC group did have an issue with the identification of aftereffects, this would be primarily for negative aftereffects as negative expressions give these individuals the most trouble in day to day life and has been shown previously in other emotion processing studies (Ashwin, Chapman, et al., 2006).

This deviation from the hypothesised results did not occur due to difficulty with adaptation in general. It has been shown in this study that those with ASC showed that they could successfully adapt to tilted lines and perceive a resulting tilt aftereffect. Moreover, the expected pattern of aftereffect, where a tilt aftereffect is stronger the closer it is to the prototypical average (Clifford & Rhodes, 2005), was found across groups. This has added to our understanding of general adaptation mechanisms in ASC as previous studies had failed to account for this ability in ASC. Those with ASC do have an adaptive coding mechanism that is intact. However, it seems that due to their limited interest and drive to attend to the social world (Chevallier et al., 2012), their face-space representations for emotional expressions may be under-developed.

There are two methodological reasons why the hypothesised difficulty with negative aftereffects did not occur through. Firstly the current paradigm only offered participants the choice of responding whether the emotional expression was positive or negative. This implies that the task evokes a series of aftereffects that are extreme opposites of one another. This could have resulted in a ceiling effect. This is unlikely, however, as the results show that none of the participants were showing ceiling results for either the positive or negative aftereffect trials. The addition of extra responses/adaptation stimuli could help to guard against this and should be assessed as an opportunity when considering future work in this area.

An alternative explanation for this result could be that the task did not fully elicit adaptation behaviour, as both the control group and the ASC group performed incredibly

poorly on anti-anger trials. The lack of a group difference for negative valence aftereffects may have arisen due to the inability of the task to probe emotional expression representation in any participants. This is however, unlikely as the same task was previously apt at exploring the representation of emotional expressions through evoked aftereffects not only within the current thesis (chapter 3) but also in other published work (Skinner & Benton, 2010). However, the control group average results shown here are worryingly low and would benefit from replication.

One explanation that the ASC group in the current study showed a deficit in representing positive expression stimuli (anti-happy) could be that this is in line with the spectrum approach to ASC. Those with high ASC-traits in chapter 3 did not show an issue with the representation of anti-happy expressions whereas the ASC sample in the current study did. This could be that both groups have similar representation issues, but the ASC group's representational under-development is greater than those with high ASC-traits and effects more emotional expressions. This conclusion is difficult to support currently due to no difference between ASC and control participants in the current study for anti-angry expression aftereffects. If the results here reflected the spectrum view of ASC we would expect those with ASC to have greater difficulties on anti-angry expressions also. However, this will have to be replicated to ensure the lack of group difference seen here isn't a result of a particularly poorly responding control group, as suspected.

The ASC group also showed reduced accuracy compared to controls in identifying the emotional expressions from photographs. The difficulties seen in the adaptation task could have emerged from differences in perceiving the valence of the expressions at a number of points in the adaptation task, including at the point of adaptation as suggested above. Since there were group differences in labelling basic emotions in photos, this suggests that difficulty in the adaptation task occurred at the earliest point in perception, which would be at the point of adaptation to the adapting stimulus. This suggests deep seated emotion expression representation issues in this population.

The current study also investigated different levels of adaptation stimuli, a full strength (100%) and half strength (50%) adaptation stimuli. This was included to test prototype referenced coding in ASC. The results showed that there was no difference between those with ASC and control participants in the way they assessed aftereffects following adaptation to 50% and 100% adaptation stimuli. The current study showed that all participants were better at identifying expression aftereffects that arise from adapting to

stimuli with stronger perceptual strength. This research suggests that participants with ASC likely use a prototype referenced model of emotional expression representation. People with ASC use prototype referenced adaptive coding of facial expressions, however, due to the group differences in perceiving aftereffects seen here, it is likely that those with ASC have an underdeveloped representational system which would mean that a prototype reference system is not as informative to these individuals as it is for non-ASC individuals. Care must be taken when interpreting the results relating to 50% and 100% representational strength adaptation stimuli however, as for aftereffects arising from 50% adaptation strength stimuli for anti-anger adaptation stimuli, the ASC group did not deviate from chance levels. Moreover, the control group did not deviate from chance levels when identifying aftereffects arising from either the 50% or 100% adaptation stimuli for anti-angry expressions.

Some previous studies have found that in the typically developing population at least, the aftereffects that arise from typical expressions are stronger than those that arise from anti-expression stimuli. Therefore, the extent to which anti-expressions tap into the emotion representation system is uncertain. This could, for example, be one reason for the low performance seen on anti-angry trials across both groups. When assessing differences between typical and anti-expressions, the current study found that typical representations of happy were better able to lead to a negative valence aftereffect than anti-expressions of anger. However, the opposite was true for positive aftereffects. Anti-expressions of happy were better at leading to positive valence aftereffects than typical representations of anger. There are more basic expressions that have a negative valence than those with a positive valence. This might mean that it is more difficult to create an anti-expression adaptation stimulus that maps specifically onto any one negative expression. However, this is unlikely as Skinner and Benton (2010) showed specificity of aftereffects for 6 basic emotions to map onto their respective typical emotional expressions.

The evidence presented here shows that people with ASC adapt to emotional expression information differently to control participants, which suggests differences in the perceptual representations of emotional expression in the brain. The present results show that this is specific to afterimages arising from anti-happy stimuli which are positive, suggesting deficits in the adaptive system for positive expressions. If the representations of emotions are not as easily created in those with ASC, this would potentially lead to a lifetime of difficulty with emotional expressions and social interaction. However, this was not seen for

adaptation stimuli that lead to negative aftereffects, but this could be due to methodological issues and needs further exploration.

# Chapter 8 – Study 6

## Using a visual-probe paradigm to study attention to emotional faces in autism

### Introduction (8.1)

The results of Chapter 4 showed that people with high ASC-traits in the general population preferentially attend to emotional expression over non-emotional expressions. These results were interpreted to mean that greater difficulty with emotional expressions in real life situations led to facial expressions becoming more salient to this group, and therefore capturing attention more readily. In line with the cognitive motivational approach (Mogg & Bradley, 1998), it was suggested that the repeated difficulty with emotional expressions lowers the threshold such stimuli normally need to exceed in order to drive attentional allocation. ASC individuals have even greater difficulty with emotional expressions than those with high ASC-traits in the general population, as their social-emotional difficulties in real life have been extreme and pervasive enough to lead to a diagnosis of ASC. The spectrum framework of autism proposes that the attention bias reported in subclinical people with higher traits of autism in chapter 4 should also occur in those with an ASC diagnosis. However, the social motivation theory of autism proposes the opposite: that those with ASC have developed issues with emotional expression stimuli due to under-development of associated brain areas due to a lack of drive to attend to the social world (Chevallier et al., 2012). ASC individuals would not be expected to have increased attention for social stimuli, even when they would normally be expected to due to increased co-morbid social anxiety (Cath, Ran, Smit, van Balkom, & Comijs, 2008; Gillott, Furniss, & Walter, 2001; Hofvander et al., 2009; Lugnegard, Hallerback, & Gillberg, 2011; S. L. Smalley, McCracken, & Tanguay, 1995; Sukhodolsky et al., 2008; van Steensel, Bogels, & Perrin, 2011). These two competing hypotheses were explored in the present study.

Previous studies in the current thesis have supported research showing that people with ASC have difficulty recognising emotional expressions, particularly those with a negative valence (Ashwin, Chapman, et al., 2006; Law Smith et al., 2010; van Steensel et al., 2011). It has also been shown that the representational systems of those with high ASC-traits and those with ASC may be underdeveloped as they perform worse than low ASC-trait individuals and control participants respectively on tasks that probe expression

representation systems. This could arise from a lack of drive to attend to and engage with the social world.

However, it is thought that repeated difficulty with understanding emotional expressions could actually lead to emotional expressions gaining *increased* salience in this population; a proposition that was found for high ASC-trait individuals in chapter 4 and is in direct opposition with the social motivation theory of ASC. Some evidence for the increased salience of emotional expression information in ASC individuals has been shown previously. For example, evidence from studies that have used the pictorial emotional stroop task in ASC have found increased attention for face stimuli. Ashwin, Wheelwright, et al. (2006) conducted a pictorial emotional stroop task using valenced face stimuli and non-valenced images of objects (chairs) in a group of people with and without ASC. Participants with ASC showed a longer reaction time when responding to the coloured overlay on trials containing a face. This effect was observed in the ASC group regardless of emotional valence or gender of the face stimuli. This effect was not observed in the control group, where only angry male faces captured attention significantly more than other stimuli. The interference caused by faces in those with ASC in this study suggests that such stimuli more readily capture attention in this population.

In opposition to this, previous research using a similar dot-probe paradigm to that used in chapter 4 has not offered support for increased attention for social and emotional stimuli. For example, Moore et al., (2012) conducted a dot-probe task with social (faces) versus non-social (house/car) stimuli finding a bias for faces at 200 ms presentation times in control participants that was not present in those with ASC. The authors concluded that those with ASC have a reduced interest in social stimuli compared to controls, evidenced by the lack of attention bias compared to non-social stimuli in ASC participants. This interpretation supports the social motivational theory which suggests that people with ASC have less of a drive to pay attention to the social aspects of the world and as a result do not gain the same level of experience and understanding of social and emotional information.

However, the results of Moore et al., did not find results supportive of most clinical work employing the dot-probe, where an increased bias to emotional expression stimuli is indicative of the issues that manifest in the disorder (e.g. anxiety disorders). The work by Ashwin, Wheelwright et al., supports this more general interpretation of attention in clinical disorders and was presently supported by the results of chapter 4 with subclinical individuals with high ASC-traits. Moore et al., acknowledge that the lack of a bias for social

stimuli in those with ASC in their study could have arisen due to nature of the stimuli used. Houses and car fronts are face-like in appearance and this similarity between the social and non-social stimuli used may have obscured findings that could have become more apparent when compared to stimuli with less face-like features. For example, in Ashwin et al., (2006) above, chair stimuli were used as the non-social aspects of the study which do not have any face-like properties. Additionally, although 200 ms presentation times are known to be sufficient in typical population participants in order to observe attentional biases, research suggests that attention in ASC may be delayed and biases may not arise until later stimulus onset times of 500 ms or greater (Townsend et al., 1996).

Hollocks et al., (2013) recently studied attention for emotional faces in children with ASC. Attention biases towards positive (happy) and negative (angry) expression faces were studied using a typical 500 ms stimulus display time. The results showed no group differences in attention bias for positive or negative emotional expressions between the ASC children and control groups. This result is particularly interesting as the design used was very similar to the study presented in chapter 4. The lack of attentional bias towards emotional expressions reported in Hollocks et al., is in opposition to results reported in the current thesis in chapter, and is difficult to interpret when considering both the cognitive motivational theory and the spectrum approach to autism. The spectrum approach assumes that the bias seen in those with high ASC-traits will also be seen, perhaps to a greater degree, in those with a diagnosis.

The finding of no attention biases towards emotional expressions in children by Hollocks et al., may differ from adults with ASC. As attentional bias research is based in the cognitive motivational approach it is important to study biases for emotional expressions in adults. This is because, as a child, misunderstanding emotion expressions in ASC may have fewer consequences but the consequences get gradually more severe throughout development as individual is more immersed in the social world. The results of chapter 4 were interpreted to suggest that *extended* difficulty with emotional expression stimuli throughout life would lead to a reduced attention threshold for such stimuli. Studying this in adults with ASC who have had longer to accrue negative experience with emotional expressions may give a clearer picture of whether attention biases develop in people with ASC.

In the current study, attention to emotion expressions was examined in a group of adults with and without ASC in order to further the results gathered through previous research.

Specifically, biases were explored in an adult group of participants with ASC in order to explore whether there are changes in attention for emotional expressions later in life for those with ASC. Additionally longer presentation timings of 500 ms were included rather than 200 ms used in some previous studies (e.g. Moore et al., 2012). This was employed as people with ASC have been noted to have difficulty with rapid attention allocation (Courchesne et al., 1994; Townsend et al., 1996). Since many previous studies have used both social and non-social stimuli in the same trial to look at attentional biases, the present study used only social stimuli on each trial to test if certain social information might actually capture attention in ASC.

The aims of the current study were to: (1) to investigate differences between adults with ASC and controls in attention biases towards emotional expressions, (2) explore whether there were differences in attending to the emotional expression based on the valence displayed, and (3) to test whether higher social anxiety in ASC might be associated with a larger emotional expression bias than high social anxiety individuals without ASC and those with ASC and lower social anxiety scores.

The cognitive motivational theory suggests that ASC adults should show an attention bias for emotional expressions in a similar way to those with high ASC-traits observed in chapter 4. In this case it is hypothesised that (1) ASC adults would show a biases towards emotional expressions. Additionally, as research has shown people with ASC have difficulties with negative emotion expressions, it was hypothesised that (2) the bias for negative emotional expressions would be greater in ASC than that seen for positive emotional expressions. Finally the cognitive motivational approach hypothesise that high social anxiety ASC and control individuals will have a greater bias for negative emotional expressions than low social anxiety individuals.

However, the social motivation theory of ASC and results found in Hollocks et al (2013) suggest no such bias should exist in ASC. A social motivational approach would hypothesise (1) that there will be no increase in attention to emotional expression stimuli for those with ASC and therefore (2) no greater bias for negative emotional expressions. In addition to this the social motivational theory hypothesises that (4) an attentional bias for negative expressions will be expected in high social anxiety control participants but not high social anxiety ASC participants owing to the limited attention to social stimuli that defines this theory.



## **Method 8.2**

### *Participants (8.2.1)*

The same participant pool as in chapter 7 was used in the current study

The ASC group included twenty participants (13 male) with a mean AQ of 31.79 (SD = 8.60, range = 20-46), a mean LSAS of 63.60 (SD = 31.94, range = 12 – 105) a mean age of 28.41 years (SD = 9.20, range 18-48) and a mean IQ of 113.06 (SD = 7.59, range 99-127).

The control participants were matched for age, gender and IQ prior to the two ASC outliers being identified. The control group 21 participants who had a mean AQ of 17.45 (SD = 5.95, range = 5-28), a mean LSAS of 35.86 (SD = 20.83, range 11-103), a mean age of 25.95 (SD = 5.74, range 18-45) and a mean IQ of 113.45 (SD = 7.76, range = 99-126). There were 41 participants in total

### *Stimuli (8.2.2)*

This experiment used the same materials as the dot-probe study described in chapter 4

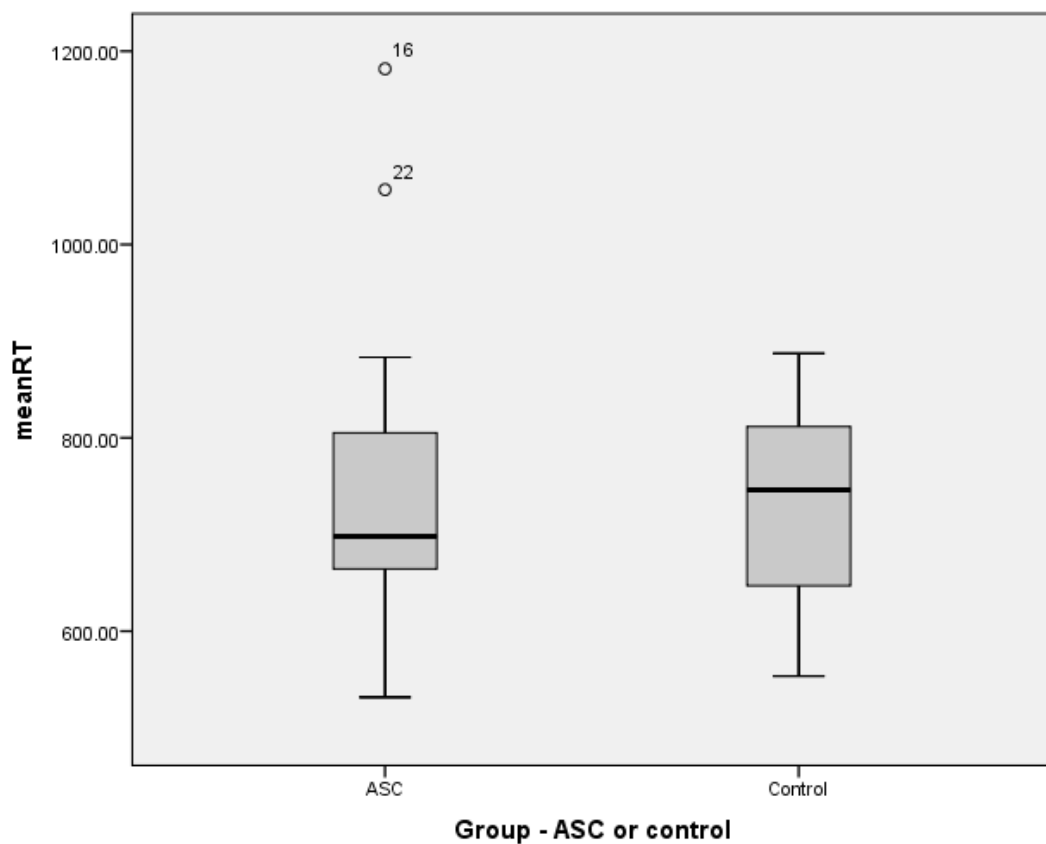
### *Procedure (8.2.3)*

This experiment followed the same procedure as the dot-probe study described in chapter 4.

## Results (8.3)

### *Outlier Data (8.3.1)*

In the current experiment, outlier RT data was removed for each participant that was faster than 200 ms as anticipatory responses, and any RT's that were longer than 2 SD above a participants individuals RT mean. This resulted in the removal 2% of the data. Following this, Box Plots were examined to identify participants whose mean RT data was an outlier above and below the average level of the participants based on 2 SD's from the mean. This revealed 2 participants whose data were considered outliers and they were removed from the analysis (fig. 8.1).



*Figure 8.1.* Box plots for both groups mean reaction times showing the two outliers for the ASC group.

Finally, once the bias scores had been created the data was checked for divergence from normality. The anger-bias in the control group was found to be divergent from normality using the Shapiro-Wilk test ( $W=.866(23)$ ,  $p<.01$ ). However, visual inspection of boxplots revealed that this was due to a further outlier with respects to bias score. It would be inappropriate to remove this individual from the analysis as an outlier. Unlike the previously removed outliers whose general reaction time data was inconsistent with other participants, a large bias score represents that an individual has increased attention for angry expression stimuli and is therefore meaningful.

The inclusion of this participant produced a violation in the assumption of normality. When the assumption of normality is broken it is more difficult to detect a true result through the use of a parametric ANOVA and this could lead to a type II error. There are two ways to remedy this. Either data can be transformed in order to restore normality or non-parametric tests can be used. As there is no true non-parametric test for a repeated measures ANOVA in order to use non-parametric equivalents would lead to breaking down the analysis into several separate analysis. This would not be helpful for the current study and multiple separate tests could lead to a type I error. Instead the data was transformed using a log transformation. Inspection of transformed data showed no violation of normality and transformed data was analysed with ANOVA. As there were no differences between the results using the transformed data and the original data, violation of the assumption of normality was not an issue and the results shown below use the original data for comparison with previous studies.

#### *Group differences following outlier removal (8.3.2)*

The two outlying participants were identified and removed from the ASC group prior to data analysis. The final groups did not differ significantly on age ( $t(30.34) = .69$ ,  $p>.05$ ) or IQ ( $t(37) = -.16$ ,  $p>.05$ ). A chi square test revealed no gender differences between the two groups ( $\chi^2(1, N = 41) = .054$ ,  $p>.05$ ). As expected, AQ ( $t(31.37) = 6.11$ ,  $p<.001$ ) and SAS differed significantly between the ASC and control groups ( $t(33.76) = 3.02$ ,  $p<.005$ ). There was no evidence of a speed vs accuracy trade-off for either the ASC (Happy:  $r = .025$ ,  $n = 20$ ,  $p>.05$ ; Angry:  $r = .192$ ,  $n = 20$ ,  $p>.05$ ) or Control (Happy:  $r = .274$ ,  $n = 21$ ,  $p>.05$ ; Angry:  $r = .396$ ,  $n = 21$ ,  $p>.05$ ) groups

#### *Dot-probe Analysis (8.3.3)*

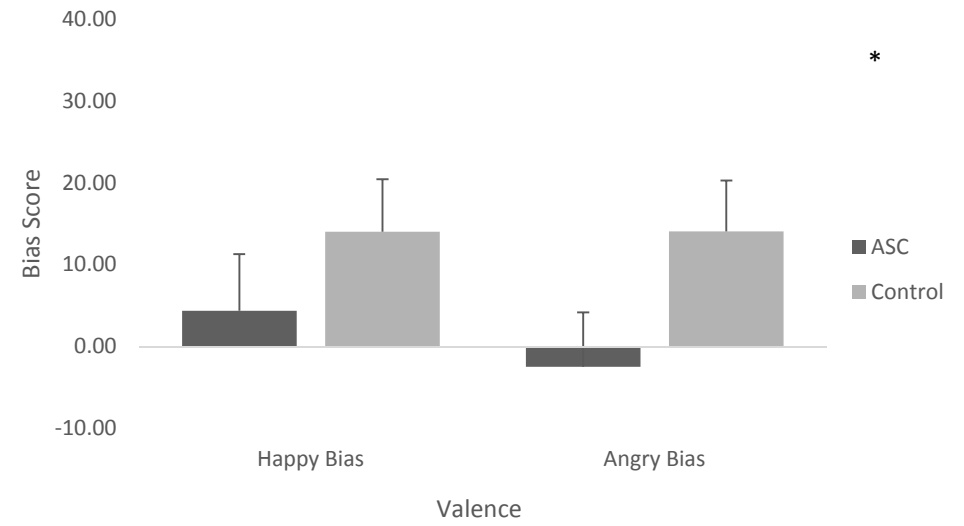
Bias scores were the DV for the analyses and were calculated as per the method described in chapter 4. These were calculated for trials containing both positive and negative emotional expressions.

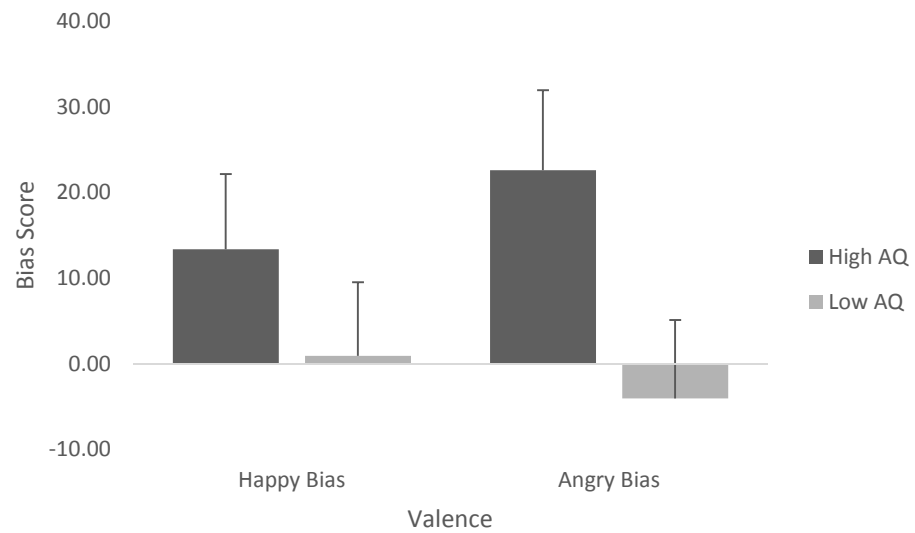
Bias score data was entered into a 2 x 2 repeated measures ANOVA with Expression Valence (Positive vs Negative) as the within-subject factors, and Group (ASC vs Control) as the between-subjects factor..

Results from the analysis revealed no main effect of either Expression Valence ( $F(1,39) = .56, p > .05$ ) or Group ( $F(1,39) = 2.63, p > .05$ ). There was also no interaction found between Group and Valence ( $F(1,39) = .58, p > .05$ , Figure 8.2).

a)

b)





*Figure 8.2.* Mean Bias scores for Happy and Angry emotional expressions for (a) High and Low AQ Groups from Chapter 4 for comparison and (b) ASC and Control groups from the current study. Error bars represent SEM. \*,  $p < .05$

To assess the attentional bias toward positive and negative emotional expressions, mean bias scores for the ASC group and the Control group were independently subjected to a one samples t-test against a test value of 0, with 0 indicating no attentional bias. This test reported that the ASC group showed no bias for either negative ( $t(19) = -.39, p>.05$ ) or positive ( $t(19) = .83, p>.05$ ) valence emotional expressions. Surprisingly, the control group showed a bias for negative emotional expressions ( $t(20) = 2.21, p<.05$ ) and a trend towards a bias for positive expressions ( $t(20) = 1.88, p=.07$ ).

In order to test whether social anxiety might have an effect on attentional biases to emotional expressions (Hollocks et al., 2013) participants were split into high and low social anxiety score groups within their diagnosis categories via a median split. The ASC group had a median SAS of 75 and the Control group had a median SAS of 36. This led to four separate groups (High SAS ASC, Low SAS ASC, High SAS Control, Low SAS Control). The High and Low SAS control groups did not vary on either AQ ( $t(20) = -1.01, p>.05$ ) or IQ ( $t(20) = .06, p>.05$ ). The High and Low SAS ASC groups did not vary on IQ ( $t(19) = -.1.31, p>.05$ ) but did show differences in AQ score ( $t(19) = -3.28, p<.01$ ) with the Low SAS ASC group having a significantly lower mean AQ than the High SAS ASC group (table 8.1).

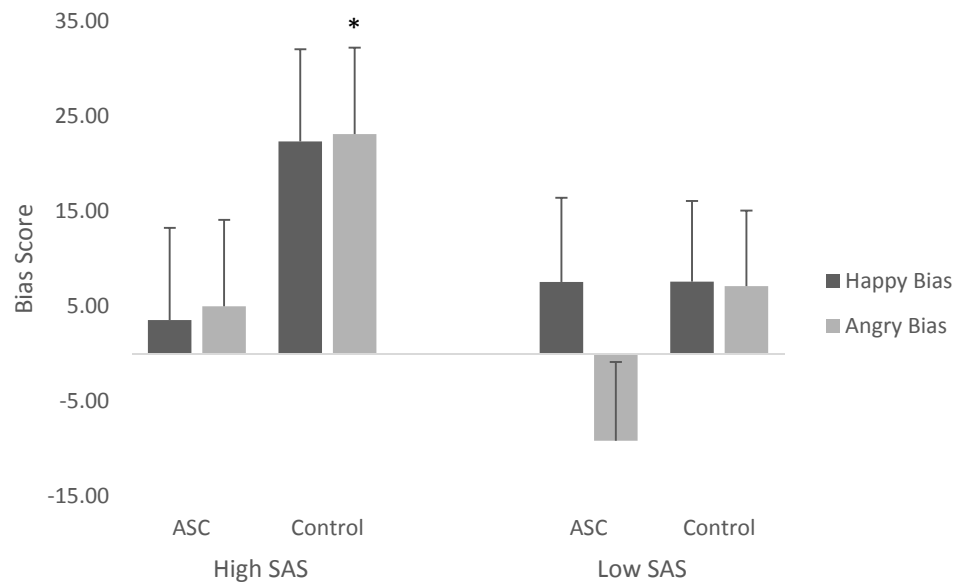
Table 8.1

*Mean psychometric and age scores for the High and Low SAS groups for Control and ASC participants*

Group	SAS	AQ	IQ	Age
ASC High SAS	92.20 (9.22)	36.80 (6.68)	114.22 (8.30)	29.80 (9.39)
ASC Low SAS	31.91 (18.17)	27.06 (6.85)	108.50 (10.47)	27.36 (9.73)
Control High SAS	51.70 (19.84)	20.10 (5.47)	110.80 (8.95)	26.10 (4.93)
Control Low SAS	19.67 (8.45)	15.25 (5.61)	115.67 (6.17)	25.83 (6.56)

A 2 x 4 repeated measures ANOVA was run on bias score data with Emotion Bias (Anger Bias vs Happy Bias) as the within subjects factor and Group (High SAS ASC, Low SAS ASC, High SAS Control, Low SAS Control) as the between subjects factor. Results showed no significant main effect of Emotion Bias ( $F(1,39) = .71, p>.05$ ), Group ( $F(3,39) = 1.63, p>.05$ ) or any interaction of Emotion Bias and Group ( $F(3,41) = 1.00, p>.05$ ).

A one way t-test performed for bias types (Happy Bias and Angry Bias) for each of the groups against a test value of 0 (indicative of no bias). Interestingly the High SAS Control group showed a significant attention bias for Angry expressions ( $t(9) = 2.29, p < .05$ ) (fig 8.3). There were no other significant biases for any groups for either positive or negative valence expressions (all  $p$ 's  $> .05$ )



*Figure 8.3* Bias scores for Happy and Angry emotional expressions for High and Low Social Anxiety ASC and Control groups. Error bars represent SEM.



## Discussion (8.4)

The current study found no group differences in attention towards either positive or negative emotional expressions between the ASC and control groups. When examining the attentional bias shown by each group, the control did show a bias for negative emotional expressions. In contrast, the ASC group showed no bias towards any emotional expressions. Further results revealed that control participants with high social anxiety showed an attention bias for angry faces, whereas the low socially anxious control participants did not show this bias. When examining the same effect in the ASC group, neither those with high or low social anxiety showed an attention bias towards faces of any valence. Together, no evidence exists for an attention bias for emotional expressions in ASC. Further to this, results do not support that social anxiety moderates attention biases for emotional expressions in ASC in the same way that it does in typically developing individuals, where higher social anxiety leads to attention biases for negative emotional expressions.

The current results are in line with the work of Hollocks et al. (2013) who did not find a bias for emotional expressions in children with ASC. Here there was also no evidence of a bias towards emotional expressions in adults with ASC. In line with the results of chapter 4, it was hypothesised that ASC adults would show a different pattern of results than the children studied in Hollocks et al., owing to a lifetime of negative issues with emotional expression information such as not understanding how expressions relate to the intentions and mental states of others compared to children who have not yet built up such experience. This hypothesis was made based on the cognitive motivational theory (Mogg & Bradley, 1998) which suggests that as people accrue more negative experience with social-emotional stimuli, their VES decreases the threshold at which similar stimuli will elicit their attention. This was not seen in the results of the current study. Most interestingly, however, when assessing high and low social anxiety within each of the control and ASC groups, controls with high social anxiety showed the expected bias towards negative emotional expressions as would be predicted under the cognitive motivational approach, but those with high social anxiety in the ASC group did not.

Hollocks et al., suggested that the high social anxiety seen in ASC could be qualitatively different than social anxiety seen outside of ASC. Although people with ASC do show the behaviour associated with social anxiety (i.e. fear of individual and group social interaction etc.) the reasons leading to this behaviour differ from typically developing individuals who have social anxiety. The avoidance of social situations (and fear associated with them) arises from a fear of negative evaluation in people with social anxiety. However, in ASC the

same behaviour could arise (avoidance and fear) but these behaviours are due to a lack of understanding of, experience with, or interest in social interactions. For example, as high social anxiety individuals tend to perceive negative expressions as a threat the level of perceived threat would act upon the Valence Evaluation System in these individuals and make them more likely to attend to threatening (i.e. aggressive) expressions in their environment. However, people with ASC are less likely to perceive emotional expressions as a direct threat, but are instead unable to identify expressions. This would lead to a lower level of threat induced by emotional expressions in those with ASC compared to people without ASC but with high social anxiety and would not act upon the same cognitive mechanisms (i.e. the VES). Therefore, the current results do not support the cognitive motivation theory of social interaction for individuals with ASC.

Instead, the current results are expected under the social motivation theory of ASC. The social motivation theory of ASC states that diagnosed individuals are less likely to be driven to engage with social-emotional stimuli in their environment. This theory suggests that differences in brain based mechanisms that drive attention, such as the amygdala, lead to less attention directed towards social stimuli in the environment. This perpetuates a cycle that leads to less experience with the social world and therefore reduced ability in social and emotion interaction. The lack of a bias for negative expressions in high social anxiety ASC participants can be explained as a lower drive to attend to emotional expressions even when they would normally be expected to attend to negative emotional expressions under the cognitive motivational theory. However, this conclusion would need re-testing with a larger sample.

In chapter 4, when examining attention to emotional expressions in a group with high ASC-traits but without a diagnosis, it was found that the attention of those with high ASC-traits was biased towards emotional expressions regardless of the valence. This was previously interpreted as an increased salience to these stimuli resulting from a lifetime of difficulty with emotional expressions. It was hypothesised here that if this was indeed the case those who have diagnosed difficulty with the emotional expressions would be expected to show a similar, perhaps accentuated, pattern of results. Owing to this, the current results do not support the spectrum approach to autism. This could suggest that although the social motivation theory of autism is appropriate for diagnosed cases of ASC, it cannot make predictions involving subclinical levels of ASC-traits. Future research could test the specificity of the social motivation to distinguish between ASC and the WAS.

However, one reason the current study didn't support this may be that the attention bias for emotional expressions may indeed exist in ASC in the same way that it has been shown in high ASC-trait individuals but could occur at an earlier time course in attention allocation. The stimulus presentation timings used in the current study may not have been able to detect it. A long exposure time of 500 ms was used in the current study owing to potential difficulties that could exist in the ASC population with regard to delayed attention orienting (Townsend et al., 1996). It may be possible to explore attention at faster presentation times in this population in a similar way to Moore et al., (2012), but this will have to be more extensively explored. The attention profile of people in the WAS with high ASC-traits could suggest that these individuals might be orienting to emotional expression stimuli at a different point (i.e. earlier or later than those with ASC) or could be attending early and maintaining their attention at later stimulus durations. Individuals with ASC on the other hand may not have such a predictable profile. It would be interesting to explore whether ASC individuals show an earlier or later onset of attention for emotional expressions and whether they show a pattern of attention orientation and avoidance over different time course of attention which was not observed using a single presentation time in the current study.

The current study was limited as it could not incorporate additional stimulus presentation timings due to time constraints. Incorporating another stimulus display duration would have doubled the length of an already lengthy procedure or halved the number of trials that could have been conducted under each stimulus display duration condition at the risk of increasing unwanted variance. However, as this thesis has delivered an understanding of how the attention mechanisms might differ in those with high ASC-traits (chapter 4) and those with ASC, a more thorough investigation is primed to take place. By employing both shorter and longer stimuli presentation durations, it becomes possible to assess whether people with ASC show a similar pattern to those with high ASC-traits, but over a different attentional time course.

In conclusion, the current results do not support the cognitive motivational theory with regards to attention for emotional expressions in ASC. ASC individuals with high social anxiety were not found to attend to negative emotional expressions in the manner expected by the cognitive motivational approach. This may mean that the social motivational theory of ASC is better equipped to explain this behaviour, but would need retesting in a larger sample. Further to this, differences seen in the way that those with high ASC-traits WAS (chapter 4) and individuals with ASC attend to emotional expressions

does not support the current theory of an autism continuum that stretches through the typically developing population. Although it is possible, and evident, that there are varying levels of ASC-traits in the general population, the extent to which these reflect the cognitive correlates underpinnings of ASC is not reflected in the current study. However, through exploration of different time courses of attention orienting in ASC the differences between those with high ASC-traits and a diagnosis of autism could be understood.

# Chapter 9

## General Discussion

Together, the results obtained from the studies presented throughout this thesis enhance our understanding of the mechanisms underlying emotion expression processing across the autism spectrum. Here, the findings will be critically reviewed and contrasted in order to gain a cohesive picture of the results and the future directions of research needs arising from them.

### **Overview of findings from Wider Autism Spectrum (Chapters 3-6) (9.1)**

Chapters 3-6 aimed to explore the differences in emotion expression processing and the mechanisms that underlie those differences in people from the general population who report high and low ASC-traits.

#### *Chapter 3 (9.1.1)*

Chapter 3 tested the ability of high and low ASC-trait individuals to adapt to emotional expression stimuli in order to assess differences in how these individuals cognitively represent emotional expressions. It was found that, following adaptation, those who had higher ASC-traits were less able to identify aftereffects arising from anti-angry adaptation stimuli that typically produce a negative valence aftereffect than those with fewer traits. High-ASC-trait individuals performed no better than chance levels when identifying aftereffects arising from anti-anger adaptation stimuli. The group differences for adaptation did not seem to arise from differences in labelling emotions or valence in the initial adaptation stimuli, as individuals in the high ASC-trait group performed comparable to low ASC-trait individuals at identifying emotions from face parts or classifying positive and negative valence from expressive emotional expression stimuli. As there were no differences in non-social adaptation responses between the high and low ASC-trait groups, it is unlikely that people with high ASC-traits have deficits in general adaptive coding mechanisms. These findings suggest differences in the adaptation mechanisms for negative emotions in high ASC-traits, and there are various potential explanations for these findings.

The first interpretation is that high ASC-trait individuals have a deficit in the representation of negative emotional expressions. This was especially true when adapting to anti-angry expressions that are designed to lead to negative valence aftereffects. This interpretation

would suggest a deficit in the adaptive coding system in these individuals that would make them unable to cognitively represent a full range of negative emotional expressions. This ties in with the literature in the ASC field where people with ASC show a specific deficit for identifying negative emotional expression stimuli (Ashwin, Chapman, et al., 2006; Law Smith et al., 2010) and people with high ASC-traits who have difficulty identifying subtle negative emotional expressions (Poljac et al., 2013). This is also supportive of the social motivation theory as it suggests that the mechanisms underlying these abilities are underdeveloped, potentially due to less drive to interact with emotional expression stimuli. These findings and theory are linked to the amygdala, which is involved in processing negative emotions. Although the amygdala was not directly assessed in the current work, this there is potential for interesting future work assessing the function of this brain structure in similar studies.

Another potential explanation is that the high ASC-trait group's deficit may have occurred due to attention differences when viewing either the adaptation stimuli or the briefly presented probe face. As negative emotional expression information is based in the eye-region (Eisenbarth & Alpers, 2011), perhaps the high ASC-trait group had reduced attention for this region similar to those with ASC (Kliemann et al., 2010) and this impacted performance during the study. Further to this, if there are attention differences that exist in high ASC-trait individuals, this could be suggestive of limited experience with emotional expressions throughout life. In line with the social motivational theory, this would impair the groups' development of their cognitive representations of emotional expressions. This could explain the poor performance for negative emotion expression adaptation in the high ASC-trait group.

Adaptation generally results in a subtle emotion expression aftereffect. Subtle expressions are defined as expressions that are perceptually closer in face-space to the prototypical norm than a more expressive emotion (Clifford & Rhodes, 2005; Tsao & Freiwald, 2006). For individuals with an underdeveloped face-space, a subtle expression has even less perceptual distance from a neutral or "prototypical" expression and therefore is more difficult to successfully and consistently derive meaning from.

Chapter 4 assessed attention biases to emotional expression stimuli in people with high and low ASC-traits. In line with the social motivation theory of ASC it was predicted that there would be reduced attention for, and interest in emotional expression stimuli. However, in contrast to this, the cognitive motivational approach hypothesises that difficulties with emotion expressions in real life would lead to increased salience for such stimuli in high ASC-trait individuals. In addition to this, it was hypothesised that high-ASC-trait individuals would show an increased bias for negative expressions over positive emotional expressions due to research that suggests greater difficulty with negative emotional expressions.

This chapter revealed that those with high ASC-traits paid more attention to emotional expressions than those with fewer ASC-traits. In line with the cognitive motivational theory, this was interpreted to suggest that those with high ASC-traits have developed increased attention for threat-related emotional expressions due to the repeated difficulty they have had with emotional expressions over the course of their life.

These results have implications for chapter 3. As those with high ASC-traits were shown to attend more to emotional expression stimuli and the increased attention should aid the development of brain regions and cognitive mechanisms underlying emotion expression representation. The constant experience with facial expressions these individuals are attending to would predict a typically developed representational face-space under the social motivation theory. The results from chapter 4 showing increased attention and drive to attend to emotional expressions is difficult for the social motivation theory to explain. However, chapter 3 concluded that those with high ASC-traits have deficits with the representation of *subtle* negative emotional expressions. Chapter 4 used explicit emotion expression stimuli. It is not certain that those with high ASC-traits pay similar attention to subtle emotional expressions. It could be that the development of face-space in high ASC-trait individuals is typical for extreme representations of emotional expressions, but atypical for mild expressions. Using subtle emotion expression stimuli in a dot-probe paradigm could be an interesting avenue to explore in order to address this point, but this requires further testing.

The results of chapter 4 do not support the social motivation theory of autism, at least for expressive emotional expressions. Instead the results support a cognitive motivation approach in this population, whereby issues with emotional expressions increase their salience over time.

### *Chapter 5 (9.1.3)*

Chapter 5 explored whether the social motivational theory of ASC would apply to those with high ASC-traits, but without a diagnosis of ASC by using eye-tracking of emotionally expressive faces. The social motivation hypothesis would suggest that these individuals would not redirect their initial gaze to areas of social importance on emotional expressive faces. In addition to this the social motivational approach would suggest that those with high ASC-traits would have atypical gaze patterns towards the socially relevant features of the face, defined here as the eyes and the mouth. The results did not support the social-motivational hypothesis, as those with high ASC-traits showed no difference in the number of fixations or dwells for eye and mouth regions over the course of the presentation of facial emotion expression.

Differences were found for first fixations to the eyes and mouths of expressive faces for high ASC-trait individuals. This difference was for increased fixations towards the eye region of negative expressions. Again, this would not be expected under a social motivation approach where it would be predicted that those with high ASC-traits would be predicted to show less interest in these areas. Instead, the results of chapter 5 support the cognitive motivation theory. The cognitive motivation theory would suggest that because negative expressions have given high ASC-trait individuals difficulty over time, their VES would have a lower threshold for such stimuli. As the eyes have been shown to be the most expressive area of an angry face (Eisenbarth & Alpers, 2011), it is not surprising that under this approach, increased first fixations to the eye region of such stimuli were found.

However, the high ASC-trait group did not show a preference for attending to the eye region of positive valence emotional expressions. This would also be expected under a cognitive motivational theory, as these expressions do not give these individuals as much difficulty. The cognitive motivational theory would not predict that the eye region of happy expressions would attract more attention in these individuals.

This study helps to interpret the results of chapter 3. It was suggested that perhaps the results arose due to attention differences in the two groups interfering with the adaptation process. As people with high ASC-traits had no differences in overall attention to positive and negative emotional expressions, this is unlikely to be the case. In addition to this, high ASC-trait individuals paid more initial attention to the eye region of angry faces than the



mouth. This supports that attention differences during the briefly presented probe face would not have driven the effect seen in chapter 3, as they would have been more likely to attend to the most informative aspect of the negative valence face (eyes).

In addition to the above findings, people with high ASC-traits were found to have their attention captured by whichever facial feature (eyes or mouth) presented at the point of initial fixation. This is in opposition to the low ASC-trait group who moved their fixation away from the mouth region when this region was presented at the point of initial fixation. This result suggests that one difficulty seen in emotion expression processing in those with high ASC-traits could in part arise from problems with disengaging attention and attending to more relevant social features.

#### *Chapter 6 (9.1.4)*

Chapter 6 explored subtle and extreme emotion expression identification in people with high and low ASC-traits. Chapter 6 used extreme and subtle representations of emotional expressions in order to explore whether people with high ASC-traits have difficulty with emotion expression recognition when the presented expression is subtle. Although this study did not find a difference in accuracy between the high and low ASC-trait groups for subtle emotion expression identification, the high ASC-trait group were found to take longer to respond to subtle emotional expressions. Importantly, when errors were made on subtle emotion expression stimuli, those with high ASC-traits were more likely to assume that the emotional expression was neutral (i.e. perceive no valence).

The results of chapter 6 help to interpret the findings in chapter 3. As those with high ASC-traits were more likely to assume subtle emotion expressions had no valence, this hints at mild deficits in the representational system for emotional expressions in these individuals. A difficulty in representing subtle emotional expressions would not only lead to a poorer adaptation aftereffect, but would also lead to difficulty when obtaining information from subtle emotional expressions. A subtle expression is perceptually closer to the prototypical norm than a more expressive emotion. For individuals with an underdeveloped face-space, a subtle expression has even less perceptual distance from a neutral or “prototypical” expression and therefore is more difficult to successfully and consistently derive meaning from.

#### *Summary (9.1.5)*

Taken together the results from chapter 3-6 suggest that there is a mild emotion expression processing deficit in people from the general population with high ASC-traits. The results from chapters 3 and 6 suggest that this arises from a deficit with the representing mild emotion expression stimuli in this population. However, the increased attention for negative emotion expressions suggests that this does not arise from atypical drive to attend to the social world as would be hypothesised by the social motivation theory of ASC. Instead it seems that the existing mild difficulties with emotion expressions leads to increased attention of such stimuli as would be hypothesized by the cognitive motivation theory. It is important to examine this with relation to clinical ASC in order to judge similarities and differences in the underlying cognitive mechanisms associated with emotion expression processing across the continuum of autism. The studies assessing this will now be discussed.

### **Overview of findings from ASC (Chapters 7&8) (9.2)**

Chapters 7 and 8 focussed on adaptation to emotional expressions using typical- and anti-expression adaptation stimuli and attention to emotional expressions using the dot-probe in adults with ASC.

#### *Chapter 7 (9.2.1)*

Chapter 7 replicated the adaptation study in chapter 3 with a sample of individuals with ASC and control participants matched for age, gender and IQ. Due to the results seen in the high ASC-trait sample it was hypothesised that, in line with the social motivation theory of autism, those with ASC would also show poorer accuracy on the adaptation task compared to control individuals. Further, it was hypothesised that the deficit would be more apparent for negative expressions due to the deficits reported for negative emotion expression processing in ASC leading to larger issues with these stimuli over time.

The study showed that those with ASC had reduced accuracy compared to control participants when identifying aftereffects, but this result was seen for aftereffects arising from anti-happy expressions that generally appear positive rather than negative. Those with ASC also showed reduced accuracy on emotion expression recognition in a separate task within the study. For the ASC group only, accuracy on emotion expression recognition positively correlated with ability on the emotion expression adaptation task. These results were found in the presence of intact non-social adaptation for individuals with ASC.

The deficit for recognising emotional expression aftereffects that typically have a positive valence mirror results found previously with adaptation studies in ASC (Rutherford et al., 2012). The social motivation theory interprets this result as an under development of the face space and mechanisms associated with the representation of emotional expressions as a result of less experience and engagement with emotional expressions throughout life.

These results were different to those found in the ASC-trait sample as those with ASC had a difficulty with aftereffects arising from anti-happy stimuli that ordinarily appear positive in valence whereas people with high ASC-traits showed difficulty with anti-angry stimuli which typically generate negative aftereffects. The different result seen between the high ASC-trait group and those with ASC could suggest that different mechanisms are at work in these two populations that both lead to difficulty with emotion expression information. However, one explanation for the difference could be the control group's poor performance seen in chapter 8. The control group showed poor recognition of the aftereffects arising from anti-angry stimuli. This could have obscured any difficulty that the ASC group have with representing negative emotional expressions during group comparisons. Replication of the current study could help to explore this further.

It is likely that the deficits seen in both the high ASC-trait and ASC groups arise from similar, but less severe, issues with emotion expression representation. The representations of emotional expression in the face-space is thought to be built up over time with increasing experience. The more experience an individual has with emotional expressions, the more likely they are to be able to develop their representational face-space in order to account for a greater range of emotional expression information. Taking a spectrum approach, people with high ASC-traits but who generally do not show severe impairments in emotion recognition have likely built up more experience with facial emotion stimuli throughout life. This is supported by the increased attention for emotion expression stimuli in high ASC-trait individuals shown in chapter 4. This would suggest typical emotion processing ability under all but the most constrained environments for those with high-ASC-traits.

The finding that those with ASC do not adapt as effectively to emotional expression stimuli helps to build understanding of the emotion expression processing deficit seen in ASC. As this group cannot adapt to such information to the same extent as non-ASC individuals as they would have underdeveloped face-space representations that do not have the same wealth of information mapped to its neural representations. This would eliminate some of the ability to effectively use adaptation as a form of gain-control and detect subtle or fine-

grain differences in emotion expressions (Clifford & Rhodes, 2005). In essence, this group are not able to perceive the same levels of emotion expression information on a neural and cognitive representational level which could result from less experience with such stimuli. An assessment of the attention those with ASC pay to emotional expressions could help interpret this in line with the social motivation theory.

#### *Chapter 8 (9.2.2)*

Chapter 8 replicated the emotion expression dot-probe study conducted in chapter 4 with individuals with ASC and matched control participants. It was hypothesised that if those with ASC have had difficulty with emotional expressions in life that they would attend more to these expressions in line with the cognitive motivational theory. Conversely, if these individuals have a lack of interest in emotional expression stimuli, as suggested by the social-motivation theory of autism, then they would not show this pattern.

It was found that contrary to the results found in chapter 4, where those with high ASC-traits showed an attention bias to emotional expression stimuli, no evidence was found for those with ASC showing this pattern. The social-motivation theory of autism would suggest that a lack of interest in social stimuli exists in these individuals and that this is moderated by reduced activity in biological substrates that help direct attention. In addition to showing no bias for emotional expressions in general, there was also no evidence of an attention bias for negative emotional expression among those with ASC who had high social anxiety. Attention bias for negative emotional expressions would be expected by the cognitive motivation hypothesis and this was found in control participants with high social anxiety.

The social motivation theory posits that the brain based mechanisms that direct social attention are underdeveloped in those with ASC. From this perspective, ASC individuals are unlikely to have a VES that functions typically for social stimuli. From the results presented in chapter 8, it is likely that the cognitive motivational theory, which would suggest that attention would be directed towards emotional expression stimuli, may not apply to these individuals when considering social-emotional attention.

#### *Summary (9.2.3)*

To conclude, it seems apparent that there are differences between the mechanisms underlying emotion expression processing in those with ASC and high ASC-traits. These

differences show that the social motivation theory of autism is able to predict the difficulties seen in those with a diagnosis and explain how they may be underpinned. For those with high ASC-traits on the other hand, the social motivation theory of autism is not as predictive of emotion expression processing. The following will discuss the social motivation theory with regards to ASC and the wider spectrum of ASC-traits.

### **The social motivation theory and the spectrum of autism (9.3)**

The current thesis was able to use the social motivation theory of autism to make testable hypothesis about how people with ASC and varying levels of ASC-traits may respond to psychological paradigms that assess social attention mechanisms and the ability to cognitively represent emotion information. If the wider spectrum of autism traits developed from the same basis as ASC, it would be considered that they should have a similar underlying basis, with differences seen in ASC being apparent to a lesser extent in people from the general population with high ASC-traits.

Although the work from the current thesis can support the predictions that the social motivation theory of autism would hypothesise regarding ASC, it cannot wholly support the theory as an account of the behaviour seen in those with high ASC-traits in the wider autism spectrum. Instead, there are stark differences between those with ASC and high ASC-traits in the general population, as shown by the differences between the hypotheses made by the social motivation theory and the behaviour seen in those with high ASC-traits.

Those with ASC perform poorly on adaptation tasks as a result of a poorly developed face-space representation for emotional expressions. Additionally, the ASC group showed limited attention to emotional expression stimuli even when other clinical models (i.e. the cognitive motivation theory) would suggest increased attention. This is consistent with the social motivation theory of autism which hypothesises that the lack of life experience and engagement with emotional expressions leads to an under developed emotion expression representation system.

In contrast to this, people with high ASC-traits were seen to have increased attention to emotion expression stimuli which is in opposition to the social motivation hypothesis. Although the findings do suggest some issues with the representation of emotional expression information for individuals with high ASC-traits, the studies presented in this thesis suggest that such difficulties have been overcome in this population through

compensatory mechanisms that imply intact social attention mechanisms. People with high ASC-traits were able to identify emotional expressions at a level comparable to those with fewer traits of ASC, which suggests a relatively intact face-space for emotional expression information. This implies that any deficit with the representation face-space for emotional expressions in this high ASC-trait individuals does not arise due to limited attention and engagement with emotion expressions. This suggests that the social motivation theory of ASC does not provide a good reason for *why* the representation systems in those with high ASC-traits may be underdeveloped.

However, those with high ASC-traits were not found to re-orient their attention to the most relevant aspects of the emotional face during eye-tracking when the mouth region was presented at the point of fixation. This issue with disengagement would be predicted under the social motivation hypothesis and may be one of the aspects that underlies the mild emotion processing difficulties seen in this group.

To conclude, the social motivation theory of autism offers an adequate framework for the results arising from ASC participant in the current study. However, the theory does not provide a framework through which to understand those with high ASC-traits but without ASC. It is suggested, therefore, that although there is evidence for the existence of the continuum of ASC-traits presented both within and outside of this body of work, there are differences in the mechanisms underlying the difficulties seen in ASC and individuals with high ASC-traits. Whereas those with ASC have reduced social motivation, people with high ASC-traits seem to have increased motivation to attend to emotional expressions and relevant social information on the face. The drive to attend to social information in high ASC-trait individuals could aid the development of brain areas that represent this information. This would leave emotion expression recognition mostly intact. Any deficits in this emotion expression processing in high ASC-trait individuals cannot be explained by a reduced drive to attend to and experience the social world. It has been shown here that on a cognitive level, the drives and mechanisms associated with ASC are different in those with high ASC-traits.

### **Limitations (9.5)**

The studies presented throughout this work took care to explore the hypothesis presented in each chapter. However, there are limitations that must be acknowledged in order to develop on work in this area in future.

The participant pool for the AQ studies was large and most studies were able to assess group differences between those with high and low ASC-traits effectively. However, in the studies that expected a small effect size, a median split strategy was used to group participants. This is a valid procedure for use in this area that has been utilised by many previous studies assessing ASC-trait differences in the general population. Using a median split does, however, mean that the highest scoring member in the low group has a very similar ASC-trait profile to the lowest scoring member in high group. However, group differences did emerge in some of the studies which shows that a median split was suitable to explore differences across the general population according to levels of ASC-traits.

An independent assessment of ASC participants using the ADOS or other clinical measure was not possible in the studies presented in this work. Instead the AQ and diagnostic reports were relied on to confirm diagnosis. The AQ scores were a relatively reliable indicator of a diagnosis in combination with clinician report, however 5 ASC sample members scored less than the 26 point cut-off recommended as indicative of an ASC. However, these members of the ASC group had consistent scores on the cognitive tasks with other higher AQ ASC individuals. This suggesting that the validity of the sample was not compromised by these low AQ scoring individuals. Future work could use a standardised clinical measure of ASC from each participant in order to secure rich data to explore what drives the differences in behaviour between those with and without ASC.

Finally, eye tracking of emotional expression faces and recognition of subtle emotion expressions in those with ASC was not conducted. These studies have previously been conducted on samples of individuals with ASC and the findings from those studies were used in order to compare against the high ASC-trait participant's performance on these tasks. Had this data been collected for the ASC, it could have been useful in order to relate to the results from the adaptation and dot-probe studies. Eye-tracking was planned with ASC participants, however, due to calibration issues within the ASC sample, not enough useable data was obtained for analysis.

## **Directions for Future Work (9.6)**

Aside from the above methodological issues there are some important future directions that have arisen from the current body of work. Throughout this thesis, it has been shown that those with high ASC-traits do not show the pattern of results on tasks that assess the underlying cognitive mechanisms associated with emotion expression processing that would be predicted in accordance with the spectrum view of ASC or under the social motivation theory of autism.

The spectrum view of autism assumes that autism stretches throughout the general population and people with the severest difficulty will obtain a diagnosis of ASC. However, an additive continuum such as this would imply similarities between those with ASC and those with high traits of ASC but without a diagnosis. Although the current work has shown some difficulties in people with high ASC-traits when representing emotional expressions, it also shows that in other areas such as attention, the opposite behaviour to that expected in ASC is observed. Importantly, this suggests that although traits that are phenotypically similar to ASC can be observed as a continuum, the cognitive mechanisms that lead to ASC are distinct to those seen in the general population with high ASC-traits.

Future work should explore this distinction in order to understand the basis of ASC. For example, the findings of the current work show that some attention mechanisms in high ASC-trait individuals focus attention towards socially relevant information. One way this could be explored further is determining whether these behaviours develop in high ASC-trait individuals as a compensatory mechanism that guards against the negative developmental issues associated with ASC. This is an important aspect to research as this could lead to the development of preventative therapies and intervention for those most at risk of developing the condition.

Further to this, the current body of work has shown that most of the predictions made by the social motivation hypothesis, while holding true for those with ASC, do not predict behaviour in those with high ASC-traits. This supports that above point, but also opens exciting avenues for future research. By utilising the social motivation approach to understand how those without ASC, but with high ASC-traits have not developed the condition could help build understanding of ASC as a condition. Through researching social motivation in people with a strong ASC phenotype but who do not have the disorder, we can understand the differences present in ASC and use this knowledge to help those most at risk of developing the condition.



Finally, since the conception of the current thesis, new measures of ASC-traits have been developed. For example, the Subthreshold Autism Trait Questionnaire (Kanne, Wang, & Christ, 2011) has been developed using the ASC diagnosis criteria and questions from the BAPQ, the SRS and the AQ. These questions and statements have been analysed for their underlying content and relevance to the DSM-IV criteria (APA, 1994). This measure has built off the existing ASC-trait measures and has been shown to account for a high proportion of the variance in scores. Future work should consider implementing this measure, at least alongside the AQ.

### **Concluding Remarks (9.7)**

The current work has shown a distinction in the cognitive mechanisms underlying emotion expression processing in those with ASC and individuals with high ASC-traits who do not hold a diagnosis. It has been suggested that the spectrum of ASC-traits is distinct from an ASC diagnosis and a continuum may run smoothly from the general population into clinical ASC. This is important for understanding the differences in these two groups and what may lead to ASC in those who do hold a diagnosis. More work needs to be done in this area guided by theories that predict a difference between those with ASC and individuals without ASC but with high ASC-traits. Studies should focus on the mechanisms underlying areas of deficit, such as attention, as these can then be targeted by interventions that can help develop a typical trajectory in those most at risk of the condition.

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